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FOREST PLANTING PRACTICE IN THE CENTRAL STATES

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Note

This is a preliminary edition of a handbook to be published by the U.S. Department of Agriculture. It is being released mainly for two reasons: (1) To serve as an interim guide for practitioners who want and need to use it until the complete publication becomes available; (2) To serve as a review copy, so that all readers may have an opportunity to submit improvement suggestions that will be considered before the final manuscript is sent to the printer.

This edition contains no illustrations; however, the captions that appear under each illustration appear in the text, so that readers may get an idea of the purpose of each photograph.

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For the past half century forest-tree-planting has been steadily increasing. Acreage planted per year throughout the nation more than doubled from 1953 to 1958. In fact, so rapid has interest in reforestation grown in recent years that, despite increased nursery production, demand for seedlings is exceeding the supply. This is a significant milestone in the history of conservation in our nation; it indicates a growing awareness of the need for making our land more productive. But the main job still lies ahead; the task of reclaiming idle land in the United States has just begun. In the Central States Region alone, for example, less than a million acres have been planted, while the best estimates indicate that nearly 8 million acres are still in need of planting (table 1). And this does not include the vast areas of cutover and poorly stocked land that could be improved by interplanting.

Table 1.--Estimated area in forest plantings and in need of planting in the Central States, 1958

(in acres)

State	Land planted[1]	Plantable land[2]
Illinois	149,557	2,817,000
Indiana	128,708	1,270,000
Iowa	50,077	502,000
Kentucky	73,245	1,439,000
Missouri	108,295	1,218,000
Ohio	234,932	563,000
Totals	744,814	7,809,000

[1]Data from Tree Planters Notes (157).

[2]Based on plantable area estimates in 1952 from "Timber Resources for America's Future" (156), less acreage planted from 1952 to 1958 taken from Tree Planters Notes (157); rounded off to nearest 1,000 acres. Estimates do not include areas of cutover and poorly stocked land where composition could be improved by interplanting.

Of the nearly 8 million acres of plantable land in the Central States, more than 95 percent is privately owned; and more than half this area is in small tracts less than 100 acres owned chiefly by farmers. The phenomenal increase in planting during the past decade is traced mainly to a growing awareness among these individual landowners of the need for and desirability to establish forest plantations. Motives for planting are varied, but the principal ones are to restore idle land to productivity, to control erosion, to establish windbreaks, and to expand areas for recreation and wild-life habitats.

Forests have contributed in great measure to our high standard of living. To maintain this standard in spite of an exploding population, we must make sure we have enough forest area. The idle land on small tracts, if planted to forests, could help assure adequate timber supplies for the future well-being of our country.

Although the ratio of successful plantations to failures has been fairly good, recurrent failures coupled with the acceleration in planting programs indicate a need for better understanding of the problems and techniques involved. Moreover, recent technological developments have outmoded practices that were standard less than two decades ago. And today, more than ever before, landowners with little experience in tree planting are seeking advice on the subject.

This handbook presents the latest available information on tree planting in the central hardwood region - where to plant, what to plant, and how to plant. It was prepared especially for people to whom landowners usually go when seeking advice on tree planting--the extension forester, farm forester, forest ranger, consulting forester, county agricultural agent, and soil conservation technician. For the Central States Region, it supersedes Farmers' Bulletins 1123, 1453, and 1994 - "Growing and Planting Hardwood Seedlings on the Farm," "Growing and Planting Conifers on the Farm," and "Tree Planting in the Central, Piedmont, and Southern Appalachian Regions."

The material presented here is aimed primarily at those interested in planting trees for timber production, erosion control, or watershed protection. Much of what is said applies equally well to planting windbreaks, shelterbelts, and Christmas trees, but the unique features of these specialty plantings are not treated. For more specific information on growing Christmas trees, other references are recommended (27) (105) (150)[1] .

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[1]Numbers in parentheses refer to Literature Cited, page 158.

The "heart" of the handbook is the "Species Selection Guides" beginning on page 129. These list species recommended for planting on the various sites within the several states. The Guides are preceded by a discussion that answers such pertinent questions as where should trees be planted, how does site affect species selection, what ground preparation is necessary, and how should trees be planted? Readers who are familiar with forestation methods may prefer to omit this preliminary, background material and turn immediately to the Planting Guides themselves.

WHERE SHOULD TREES BE PLANTED?

The first problem confronting a prospective tree planter is deciding where to plant, or, in other words, what kind of land is suitable for planting? Whether a given tract of land should be planted to trees depends upon the answers to three questions: Will trees grow there? Will it pay to grow them there? And, is it necessary to plant them there?

The answer to the first question has to do with the productivity of the land and is such an important subject that it will be considered by itself in the following chapter.

The second question has to do with economics. Whether or not it will pay to plant trees on a given area depends upon the purpose of the proposed plantation. If the purpose is to stabilize the soil, control erosion (fig. 1), or protect a watershed, the

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Figure 1.--Tree planting is an excellent way to restore badly gullied land to greater productivity and to stop further erosion.

---

plantation will "pay" if the stated purpose is accomplished. On the other hand, if the purpose is to grow a merchantable crop, whether it be Christmas trees, pulpwood, fence posts, or sawtimber, the question can be answered in terms of dollars and cents: "Can you make more money growing trees than you could growing some other crop on this land?"

Very few plantations in the area are old enough to indicate prospective sawtimber yields. There are many immature plantations, however, from which probable yields of posts and cordwood for a number of species, ages, and localities may be estimated (fig. 2)

Figure 2.--Posts and poles removed in thinning 20-year-old plantation of shortleaf pine in Missouri. This thinning yielded an equivalent of 660 posts out of a total estimated stand of 1,500 fence posts per acre. The stand was also thinned at 16 years, yielding 5.5 cords of pulpwood.

(table 2).

In many cases the decision to plant is easy. If a piece of land is obviously unsuited to growing farm crops because of erosion, location, topography, or geology, then planting trees is probably the best bet.

The third question can be answered by examining the present stocking on the area and estimating future natural restocking. If the area now has a sufficient number of well-distributed, desirable trees per acre, no planting is necessary. If stocking is poor, however, and it is not likely that enough natural restocking will occur in 5 years, the area is classified as "plantable." To determine plantability on areas covered partly with desirable and undesirable trees, sample tallies should be taken to determine stocking by species. Because distribution of the desirable trees is also important, do not count more than one desirable tree on each milacre (6.6 feet square) sampled. Two standards of stocking are presented: fair and good (table 3).

Table 2.--Sample yields of immature plantations in the Central States

Species	Location	Thinnings		Growth and yield			
		Age	Vol. removed per acre	Age	Dbh[1] av.	Ht.[1] av.	Vol. per acre[2]
		Years		Years	Inches	Feet	
Shortleaf pine	Southern Illinois	17	1/4 stand	20	5.9	33	17 cords
	Southern Ohio	Not thinned		23	7.0	42	17 cords
	Southern Indiana	14	3.2 cords				
		21	8.6 cords	21	7.1	40	20 cords
	Missouri Ozarks	16	5.5 cords				
		20	660 posts	20	7.5	40	840 posts
Loblolly pine	Southern Illinois	13	318 8ft. mine props and 183 7 ft. posts	17	7.4	44	15 cords
Eastern white pine	Eastern Iowa	Not thinned		51	10.9	70	33,467 bd. ft.
	Northern Illinois	34	2,742 bd. ft.				
		39	1,746 bd. ft.	39	8.9	53	16,123 bd. ft.
Eastern red-cedar	Northern Arkansas	No thinning records		44	6.0	40	5,866 posts
Red pine	Southeastern Ohio	Not thinned		41	8.5	52	10,324 bd. ft.
Cottonwood	Missouri						
	Not thinned			14	8.9	82	20.97 cords
	Thinned	8	3 cords	14	10.0	82	20.29 cords
Sweetgum	Southeastern Ohio	Not thinned		40	8.3	55	14 cords
Yellow-poplar	Eastern Ohio	Not thinned		18	5.0	40	19 cords
Black walnut	Central Missouri	Not thinned		14	5.0	35	No record

[1]The average diameters at breast height (Dbh) and average heights are for trees making up the overstory of the plantation; not included are the few overtopped and suppressed trees found in most plantations.

[2]Does not include volume removed in thinnings. Board-foot volumes from tables based on International 1/4" log rule.

Table 3.--Stocking standards to determine plantability

Size-class[1] (Diameter at breast height) (inches)	Land is "plantable" if it has less than the following number of trees per acre for	
	Fair stocking	Good stocking
Seedlings:		
Less than 1	400	600
Saplings:		
1 - 4	200	280
4 - 6	100	200
Poles:		
6 - 8	40	130
8 -10	30	80
Sawlogs:		
10 plus	10	45

[1]For a combination of two or more size-classes reduce stocking to seedlings by use of following equivalents: one sawlog tree is equivalent to 40 seedlings, 1 pole = 10 seedlings, and one sapling = 2 seedlings. Example: an acre with 3 sawlogs, 10 poles, 30 saplings, and 100 seedlings is equivalent to 380 seedlings, and therefore classified as plantable.

In the Central States there are three broad classes of plantable land, each different from the others in species suitability, productivity, and appropriate techniques for planting: (1) open, nonstocked land, (2) cutover and poorly stocked forest land, and (3) strip-mined land. The third class, strip-mined land, represents the extreme in "disturbed" sites. Here the soil has undergone complete upheaval, often to a depth of many feet, so that the resulting surface "soil" bears little resemblance to the original. These artificially created conditions are so unique that a special bulletin has been published dealing with planting on such land (75). Hence we will be concerned here only with the first two classes.

Open, Nonstocked Land

Open, nonstocked land includes prairie land that never was in forest, and land that was originally forested but at some time in the past was cleared and used for some other purpose, usually farming. This includes some land now being farmed but which is more suitable for growing trees (fig. 3), and a great deal of land once used for

Figure 3.--Some land used for agriculture, such as this worn-out, gullied cornfield should be planted to trees.

agriculture but later abandoned (fig. 4). The "old fields" of the

Figure 4.--Most of the tree planting will be done on open, nonstocked forest land, such as this typical "old field" in Ohio.

Central States are typical of nonstocked forest land that should be planted to trees. Most tree planting will be done on this kind of land.

The landowner's decision to plant or not to plant such land should rest mainly on the possibility of the land restocking naturally to a forest (118) of desirable trees within a reasonable period of time, say 5 years. In old fields examined in central Missouri by Drew (39) 30 to 35 years after abandonment, sassafras and persimmon were still found to be prominent components of the cover, "suggesting a long interval of time prerequisite for reestablishment of such forest conditions" as existed before the land had been cleared for agriculture.

When debating this question, several points should be considered. Size of the potential planting site is of primary concern. A large parcel of land, most of which is a long way from natural seed sources, will take much longer to revert to forest than a smaller one. The rate at which this succession proceeds depends on a number of factors, the most important of which are the size of the area, proximity to seed sources of desirable species, and site conditions. In a study of 60 randomly selected old fields adjacent to forest land in southeastern Ohio, the principal factor influencing the rate of succession was the size of the field (91): the smaller the field the faster it reverted to forest. Then too, in order to depend on the natural development of a good forest, there must be seed trees of desirable species in adequate numbers nearby. And finally, the site must be in such condition that the desirable trees can become established, survive, and grow without undue competition from associated herbaceous and brushy vegetation.

According to the Illinois Technical Forestry Association (63): "The best sites usually develop blackberry briars or hardwood brush within 2 to 4 years. Medium to poor sites gradually pass from annual weeds and grasses through broomsedge or other perennial grasses and eventually into briars and brush. The poorer the site, the longer this ecological succession requires. Heavily eroded sites in southern Illinois with all the A and part of the B soil horizon removed may require 10 years or more to come into broomsedge and another 10 to 20 years to form a moderately full cover of brush and briars. Such areas often will not, unaided, develop a full stand of desirable trees for a hundred years or longer." Because of the loss of productivity through erosion and changes in the land surface, some kinds of trees suited to the former conditions of the land are no longer suitable.

Some prairie and grassland may be best suited for growing trees even though it has never supported a forest cover (80). Dry, exposed bluffs along the Missouri River in Iowa and many regularly flooded bottomlands are examples. Except for shelterbelts and landscaping, most of the trees planted on such land will be for posts, poles, Christmas trees, and fuel; it is doubtful whether high-quality sawtimber could be produced on these sites, particularly on the heavy, fine-textured prairie soils. For example, the growth of white pine, Scotch pine, European larch, and Norway spruce on some prairie soils in Illinois was normal during the first 30 years after planting and then sharply declined and stagnated (79). The growth pattern of hardwoods on prairie soils, though not as striking as that of conifers, shows similar trends (168).

Cutover or Poorly Stocked Land

"Cutover land" as used here is land that has been logged but not cleared for any other use. "Poorly stocked land" is land that has been open in the past but now is more than half covered with trees. It may either be prairie land or old fields that is being invaded by trees but is only partially stocked with desirable species. To be classed as "poorly stocked" and "plantable" each acre should: (1) have more than half its surface covered by a canopy of tree crowns (fig. 5), (2) have less than the prescribed

Figure 5.--Natural succession has proceeded so far on this old field that in a few years it can no longer be classified as "poorly stocked."

maximum number of trees of desirable species (table 3), and (3) be not likely to become stocked naturally to the minimum number of trees of desirable species within 5 years (fig. 6).

Figure 6.--Only the edge of this old field has become well-stocked with yellow-poplar. The field has not been cultivated for more than 30 years, and not grazed for 17 years.

Much cutover land does not, of course, need planting. Most of the planting on cutover land will be on areas so severely burned or logged that there is little likelihood of natural restocking to desired species within a reasonable period of time.

Site conditions for planting on poorly stocked old fields are more like those of cutover land than nonstocked, old fields. Some soil properties have been improved by the presence of the trees (32), (9); leaf litter covers part of the ground and some duff and humus--typical of forest soils--are being formed. The "microclimate" resulting from tree cover is, moreover, much different than on open, nonstocked land. For these reasons poorly stocked old fields are grouped with cutover land in the classification of land for planting; nonstocked old fields are grouped with prairies and grasslands (table 3). "Cutover or poorly stocked land" therefore includes (1) old fields or prairie land that has more than 50 percent of each acre covered with trees, but has less than the maximum desirable trees to be plantable (table 3), and is not likely to restock to the minimum number of desirable trees within 5 years; (2) cutover land, regardless of stocking, that does not have the number of desirable trees per acre to be well stocked and not likely to regenerate naturally to the number of desirable trees per acre in 5 years; or (3) forested land, regardless of stocking, where conversion (101) (173) plantings are desired (fig. 7).

Figure 7.--This site, formerly supporting a stand of defective low-quality hardwoods, has been cut over and planted to loblolly pine. "Conversion plantings" of this kind usually require one and sometimes two additional releases after the pine has been planted to assure good stocking.

HOW PRODUCTIVE IS THE LAND?

A knowledge of the productivity of land is as essential to the forester as it is to the agronomist or the horticulturist. A choice of planting jack pine or black walnut on a certain site, for example, may affect potential returns as much as a choice between strawberries and corn, or between apples and blueberries. The suitability of land for different farm crops, based on such well-known properties as texture, tilth, plowability, and fertility, has been studied for centuries. Out of this study and practice has evolved a classification of certain soil properties that helps the farmer select the best crop for his land. Although some of these well-known soil properties are useful in judging land for timber growing, other properties have recently been found to be equally as important (165) (33). Considering these site factors in choosing species for planting should increase the chances of success. The descriptions of site factors that follow are intended to help in recognizing them on the ground. Sources of additional help are discussed in the section "Where to Get More Help," page 125.

The soil itself is one of the best indicators of site productivity. So the planter should be familiar with the characteristics or properties that make one soil better than or at least different from another in its capacity to grow trees. Unlike the situation for agriculture, nutrient deficiencies are seldom critical in tree growing: most soils contain more than enough mineral nutrients to support some kind of tree growth.

To compare the productivity of one area with another, foresters use the term "site index," based on the average heights of dominant trees in a stand at a specified age--usually 50 years. For example, an area with a site index of 40 for eastern white pine is regarded as a poor site, while an area with a site index of 70 is a good site.

Soil Texture

One of the soil properties of most concern in tree planting, however, is texture--the relative amounts of sand, silt, and loam. Texture is important chiefly because it influences drainage and hence the amount of water and air the soil will hold. Coarse-textured or sandy soils are well drained and aerated but soon become dry with lack of rainfall (except sands with high water tables). At the other extreme are the fine-textured soils or clays which can hold much more water than the sands and hold it longer. Some of this water, however, is held so firmly that it is not available for absorption by plant roots. The best soils are the loams--mixtures of sand, silt, and clay--which combine the good attributes of all. So, if the planting site is loamy, the planter has a wide choice of species to choose from; if the soil is at one extreme or the other in texture, his choice is more limited and must be made with greater care.

The Soil Survey Manual (153) outlines generally accepted soil textural terms as follows:

Sandy soils-- coarse-textured soils

- Sands
- Loamy sands

Loamy soils

- Moderately coarse-textured soils
  - Sandy loam
  - Fine sandy loam
- Medium-textured soils
  - Very fine sandy loam
  - Loam
  - Silt loam
  - Silt
- Moderately fine-textured soils
  - Clay loam
  - Sandy clay loam
  - Silty clay loam

Clayey soils-- fine-textured soils

- Sandy clay
- Silty clay
- Clay

If there are a large number of stones in the soil, the textural class is often prefixed by such descriptive words as "stony," "shaly," or "gravelly."

In the fine-textured soils of southern Ohio and Indiana, Gaiser and Merz (50) found that site index for red and white pine decreased as the percentage of silt and clay in the topsoil increased. But sands, which contain less silt and clay than do sandy loams, are generally less productive than the sandy loams.

Closely related to soil texture are two other important soil properties -- structure and consistency. Structure refers to the arrangement of soil particles in clusters or aggregates; consistency refers to the plasticity, stickiness, cementation, or hardness of soils.

Depth of Topsoil

Recent research (8) (50) in many parts of the United States and on several species, has shown that the thickness of the topsoil or A horizon[2], is one of the most important single factors affecting tree growth (fig. 8). The thickness of the topsoil varies from place to place from zero to more than 1 foot, depending on topography, origin of soil, extent of erosion, native vegetation, and many other factors. A horizons of most prairie soils are usually darker colored and thicker than forest soils.

[2]The topmost layer of an undisturbed soil, usually darker in color than the subsoil (B horizon), due chiefly to the presence of more organic matter. The combined A and B horizons are known as the "solum" and the substratum or parent material is the C horizon.

Figure 8.--Relation of site index of red and white pines to thickness of topsoil and percent silt and clay (50) unglaciated parts of Ohio and Indiana.

Plowing obviously changes the character of the land surface. On plowed sites, where the depth of the A horizon was less than plow depth, some of the subsoil material is mixed with the topsoil. If the soil down to plow depth is different in appearance from the soil beneath it and is more like the original topsoil in color, texture, friability, and so forth, it is classified as topsoil. This layer is sometimes called the Ap horizon. If so much of this horizon has eroded away that the remaining upper layer looks like subsoil, it should not be regarded as topsoil.

Although the topsoil thickness is not always related to degree of erosion, the two are usually so closely linked that for the purpose of site classification for tree planting they are considered jointly.

Five classes of topsoil, based on their thickness and degree of erosion, are generally recognized:

0. Very deep. No erosion. More than 14 inches thick on more than 75 percent of the area.

1. Deep. Little or no erosion. Seven to 14 inches in thickness on more than 75 percent of the area.

2. Moderately deep. Moderate erosion. Three to 7 inches over more than 75 percent of the area. On land that has been plowed some of the material is made up from subsoil or B-horizon material.

3. Shallow. Serious erosion. Less than 3 inches of topsoil over more than 75 percent of the area. On land that has been plowed the top layer may be made up mostly of subsoil or even material from the substratum.

4. Gullied. Most of area with an intricate pattern of gullies, too deep and too numerous for planting machines. Nearly all of the A and much of the B horizons gone except a few spots between gullies.

On some alluvial sites along rivers and streams, there are no well-defined A, B, and C horizons. The surfaces of these lowland sites contain much topsoil recently washed down from upland soils. Older alluvium, however, may well have developed surface soil overlying plastic, mottled subsoils.

Effective Rooting Depth

The depth to which good root development may occur is termed "effective rooting depth"; it is an important factor to consider in the choice of species for planting (96). Effective rooting depth can be defined as the depth of the soil to the point below which there are few if any roots less than 1/4 inch in diameter. Although there may be a concentration of small roots in the topsoil, some subsoils may also have a large volume of small roots. Good root development depends upon soil properties, (texture, structure, and consistency), the thickness of horizons, and a suitable balance between soil moisture and soil air. The effective rooting depth is limited by: (1) material that restricts further downward development of roots, such as a water table, solid bedrock (fig. 9), hard-

Figure 9.--Solid bedrock near land surfaces restricts effective rooting depth of trees. Such sites as a rule are droughty and not as productive as those with deeper soils.

pans, and in the case of land cultivated for many years, the plow-sole; or (2) material too coarse to be called "soil" such as fragmented bedrock, gravel, and loose shale (fig. 10).

Figure 10.--Shallow loessal soil material with a highly permeable stony substratum. During periods of deficient rainfall these soils are droughty.

Drainage

Drainage (i.e. water movement over and through the soil) greatly affects the balance of moisture and air in the soil. It is related chiefly to topography; texture, structure, thickness, and character of the litter and duff on the soil surface; permeability of the soil; depth to, thickness, and permeability of hardpans, substrata, and bedrock; and the depth to the water table. Many other factors are also involved, but for planting-site evaluations these need not be considered.

"Variations in soil drainage can be related by inference to differences in soil color and patterns of soil color" (153). Gleying, a term used to describe the process caused by waterlogging and lack of oxygen, gives some soils a neutral gray color. Soils mottled with yellows and grays, caused by intermittent waterlogging, are usually poorly drained. Soil color, however, also varies according to the vegetation under which the soil has formed. In the Central States soils formed under forest vegetation are characteristically brown, gray-brown, or gray, while those developed under prairie or grassland vegetation are dark brown or black.

The following general soil-drainage classes, based on soil color and topography and reflecting rates of runoff, soil permeability, and internal soil drainage, were developed by the Soil Conservation Service (153) and should aid in classifying soils for tree planting:

"0. Very poorly drained.--Water is removed from the soil so slowly that the water table remains at or on the surface the greater part of the time. Soils of this drainage class usually occupy level or depressed sites and are frequently ponded. Very poorly drained soils commonly have dark-gray or black surface layers and are light gray, with or without mottlings, in the deeper parts of the profile. In the grassland regions, very poorly drained soils commonly have mucky surfaces with distinct evidences of gleying.

"1. Poorly drained.--Water is removed so slowly that the soil remains wet for a large part of the time. The water table is commonly at or near the surface during a considerable part of the year. Poorly drained conditions are due to a high water table, to a slowly permeable layer within the profile, to seepage, or to some combination of these conditions. In the podzolic soil region, poorly drained soils may be light gray from the surface downward, with or without mottlings. Among the dark-colored soils of the grasslands, poorly drained soils commonly have slightly thickened dark-colored surface layers.

"2. Imperfectly or somewhat poorly drained.--Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Imperfectly drained soils commonly have a slowly permeable layer within the profile, a high water table, additions through seepage, or a combination of these conditions. Among the podzolic soils, somewhat poorly drained soils are uniformly grayish, brownish, or yellowish in the upper A horizon and commonly have mottlings below 6 to 16 inches in the lower A and in the B and C horizons. Among the dark-colored soils of the grasslands, somewhat poorly drained soils have thick, dark A horizons, high in organic matter, and faint evidences of gleying immediately beneath the A horizon.

"3. Moderately well drained.--Water is removed from the soil somewhat slowly, so that the profile is wet for a small but significant part of the time. Moderately well-drained soils commonly have a slowly permeable layer within or immediately beneath the solum, a relatively high water table, additions of water through seepage, or some combination of these conditions. Among podzolic soils, moderately well-drained soils have uniform colors in the A and upper B horizons, with mottling in the lower B and in the C horizons. Among the dark-colored soils of the grasslands, profiles have thick, dark A horizons and yellowish or grayish faintly mottled B horizons.

"4. Well drained.--Water is removed from the soil readily but not rapidly. Well-drained soils are commonly intermediate in texture, although soils of other textural classes may also be well drained. Among the podzolic soils, well-drained soils are free of mottlings (except for fossil gley), and horizons may be brownish, yellowish, grayish, or reddish. They may be mottled deep in the C horizon or below depths of several feet. Among the dark-colored soils of the grasslands, well-drained soils have thick, dark A horizons; reddish, brownish, or yellowish B horizons; and C horizons that may or may not be mottled. Well-drained soils commonly retain optimum amounts of moisture for plant growth after rains or additions of irrigation water.

"5. Somewhat excessively drained.--Water is removed from the soil rapidly. Many of the somewhat excessively drained soils have little horizon differentiation and are sandy and very porous. Among podzolic soils, somewhat excessively drained types are free of mottling throughout the profile and are brown, yellow, gray, or red. Among the dark-colored soils of the grasslands, many profiles have relatively thin A horizons; brownish, yellowish, grayish, or reddish thin B horizons; and no mottlings within the solum. Only a narrow range of crops can be grown on these soils, and the yields are usually low without irrigation.

"6. Excessively drained.--Water is removed from the soil very rapidly. Excessively drained soils are commonly lithosols or lithosolic (with little or no soil profile development), and may be steep, very porous, or both. Shallow soils on slopes may be excessively drained. Among podzolic soils, excessively drained types are commonly brownish, yellowish, grayish, or reddish in color and free of mottlings throughout the profile. Among the dark-colored soils of the grasslands, profiles commonly have thin A horizons (except for sand types that may have thick ones)."

Pines, as a group, are unsuitable for planting on poorly drained soils. Among the conifers, baldcypress is perhaps the most tolerant of wet conditions. Hardwoods differ in their tolerance of periodic flooding (179); there are apparently few if any adverse effects of flooding on hardwoods during the dormant season. Mortality caused by flooding during the growing season, however, is high for some species even after they have become well established. In a study of the effects of various periods of summer inundation on the mortality of pole-sized trees or larger, Williston (172) found that all yellow-poplars flooded 19 days died, and those flooded for only 10 days were damaged. Sixty percent of the red oak and 62 percent of the white oak flooded for 21 days died. Eighty-six percent of the sweetgum, and 73 percent of the red maple survived after being inundated for at least 21 days.

Aspect and Topography

The direct and indirect effects of position on the slope and of aspect on tree and soil development are difficult to separate. The direct effects are differences in microclimate brought about by differences in slope position or aspect. Temperatures, evaporation rates, and sunlight intensity are lower on northerly aspects than on southerly aspects. Winds are generally stronger on upper slopes than on lower slopes; and in areas of sharp relief there may be marked differences in precipitation and wind velocities among all aspects. Among the indirect effects sometimes associated with differences in slope position or aspect are differences in soil thickness, texture, and structure; available soil moisture; acidity; permeability; and drainage.

Gaiser and Merz (50) found that aspect, topographic position, and slope had little effect on the growth of red and white pines planted on old fields in southeastern Ohio and southern Indiana. Similar results were reported by Allen (2) for shortleaf, loblolly, Virginia, and white pines; yellow-poplar; and black locust plantations in the Tennessee Valley. But, because these plantations were chiefly on old fields, most of them were not located on extremely steep slopes. Gaiser (49) and Doolittle (38) have reported definite relations of site index of trees in natural stands to slope position and aspect when all degrees of slope are considered. Steep slopes are more common on cutover land than on old fields, and on these sites, aspect and steepness are more important to consider in selecting species for planting than they are for old fields in the southern parts of the region.

Although there are no doubt differences in site quality among aspects and slope positions, in some localities there is generally not enough difference in tree development on such sites to affect choice of species. However, for certain species and sites such as conifers in the prairie regions and yellow-poplar (132) on cutover land in the southeastern part of the region, slope and aspect need more careful consideration.

Slope positions are most often classified as upper and lower, while aspects are classified as northern and eastern, and southern and western.

Parent Material

The parent material (rock from which soils are formed) for most of the upland soils in the southern half of the Central States is underlying, consolidated rock (fig. 11). Parent materials are

Figure 11.--General location of principal parent materials of soils in the Central States. From Atlas of American Agriculture (151).

predominantly sandstone, limestone, shale, dolomite, and clay. Extreme variations occur in texture, permeability, topsoil depth, and other soil properties. Original forest cover was chiefly hardwoods, but pines were dominant on some of the dry sites. Because of these variations in soil characteristics and topography, the species for each site should be chosen carefully.

Much of the Central States is covered by materials left by the glaciers. Glacial drift develops into various kinds of soils. Many contain stones of various sizes but are, as a whole, productive and suitable for many tree species. In Missouri, Iowa, and Illinois the original cover on glacial soils was chiefly prairie vegetation while in other parts the original cover was hardwood forest.

Lake plains, formerly covered by post-glacial lakes, are rather extensive in northern Illinois, Indiana, and Ohio. The soils in these old lake beds range in texture from coarse gravel or sand to "tight" impermeable clays. The pot-holes and depressions so common in these areas were no doubt the deepest parts of these extinct lakes.

In northern Missouri (71) and most of Iowa and Illinois, the glacial drift has been covered by wind-blown material--loess--of various thicknesses ranging up to more than 50 feet in some localities. Loessal soils are predominantly silt loams and, with alluvium, are among the most productive soils in the region. The original cover was mainly grass; forests consist mainly of hardwoods and redcedar.

Most of the soils in broad valleys and bottomlands were formed by the action of water melting from the glaciers and later overflowing from rivers and streams. These soils are variable in texture and permeability, and the original vegetation was forest in some localities and grass in others. The original forest cover was predominantly hardwoods--cottonwood, willows, gums, sycamore, boxelders, and many other species. Ground cover--grasses, shrubs, and weeds--is invariably so luxuriant on alluvial soils that it is difficult and expensive to establish plantations on them.

Colluvial soils--those developed on lower slopes and adjacent bottomlands from material that has fallen from upper slopes--are common in the hilly sections of the region. They are generally more productive than soils on slopes above them, because they are deeper and more permeable.

The mineral character of the soil, through its influence on texture, nutrient supply, and soil acidity, greatly influences the productivity of the site and the species that will grow there. Soils derived mainly from sandstone, quartzite, and sandy shales have a relatively low nutrient content; phosphorous and potash especially are lacking (169). Limestone, dolomite, and some shales have a high calcium content but also are sometimes deficient in potassium and phosphorous.

Tree growth is affected by soil acidity. Soils derived from rocks such as limestone and dolomite are calcareous or acid, depending upon how much leaching has taken place. Other soils, unless they have been limed, are acid. Some soils derived from carbonaceous or bituminous shale may be highly acid. Although there is a wide range in acidity within which most species are adaptable, some hardwoods, such as yellow-poplar and cottonwood, grow best on soils that are slightly acid to calcareous. Pines, as a group, are better suited to acid soils than are many hardwoods (45). Redcedar, European larch, and Austrian pine, on the other hand, do well on calcareous soils. Although many pines will grow when planted on calcareous soils, germination of seed is invariably poor (24) making direct seeding on this kind of soil impractical. Moreover, it would be difficult to regenerate the pines naturally for succeeding rotations.

Past and Current Use of Land

Once land has been cleared and used for pasture or for cultivated crops, the former composition of the forest is not a good guide for selecting species to plant. Tree cutting, burning, grazing, and cultivation can make profound changes in the productivity of the land (23) (fig. 12). Some of these changes, caused

Figure 12.--This land in southern Illinois at one time no doubt supported a good stand of hardwoods. Today, after severe erosion and gullying caused by plowing up and down slopes, it is more suitable for the planting of conifers.

by erosion and compaction, are obvious and can be readily appraised; others, such as changes in nutrient availability, soil structure, and the character and extent of soil micro-organisms, are not yet fully understood. Nevertheless, the performance of numerous species planted on many of these sites has shown conclusively that some species--especially hardwoods--adapted to the land before clearing for agriculture are not suitable for replanting on the area (4) (54) (55) (97). However, hardwoods can be planted on many old fields that have restocked naturally (fig. 13). On such sites, soil struc-

Figure 13.--Stages in succession of an old field: (a) first stage, vegetation composed mainly of grasses and weeds; (b) second stage, although still classed as nonstocked, seedlings and a few saplings have appeared; ground cover is still predominantly grass and weed. (c) Fully stocked with trees, grass cover absent.

ture has improved and beneficial soil micro-organisms apparently are more abundant (fig. 14) (30).

Figure 14.--Twelve-week-old yellow-poplar seedlings propagated from seed in undisturbed, potted soil samples. In A the beneficial effects of micro-organisms are apparent in both old field and forest soils; in B the seedlings in the potted soil from a fully stocked old field are as well developed as those in the forest soil. The development in the half-stocked old field soil is, however, no better than the seedlings grown in the soil from the nonstocked portion of the same old field.

Land, such as the prairies, that never supported tree growth presents different planting problems. Trees of some species planted on these sites do not attain the size or form they do in their native habitat (98). Prairie soils are often lacking in soil micro-organisms, such as mycorrhiza, that are needed for good tree growth. The selection of species for these sites therefore requires special consideration.

Forest land recently cutover, but not otherwise altered by burning, clearing, grazing, or plowing, usually provides good growing conditions for planted trees, providing care is taken that they are not overtopped by ground cover or the trees remaining in the stand. Because logging in the past may have removed the best trees in these stands, the composition of the stand before the recent cutting may not reveal the true potential of the site. Many of our defective hardwood stands formerly grew species of higher commercial value.

Because of these effects of past uses and current cover on the survival and development of plantations, it is considered necessary to recommend different species for planting on open, nonstocked land than on cutover or poorly stocked land.

WHAT KINDS OF TREES SHOULD BE PLANTED?

Selecting the species to be planted is perhaps the most critical decision to be made in advance of planting. Species chosen must be adapted to the site, the climate, and the purpose of the plantation.

SELECT SPECIES SUITABLE TO THE PLANTING SITE

This rule can hardly be over-emphasized. Most plantation failures result from not choosing the right species for each site (36). In fact if conditions differ from one part of a planting site to another, different species are often necessary.

The kind of trees that prevailed on the site before it was cleared is not always a good guide to what should be planted now. This is especially true on land that has been cleared for a number of years. So choose a species that is adapted to the site as it is today--not as it was 20 or more years ago.

Failure to predict the adverse effects of poor drainage on the survival and growth of many species of hardwoods and conifers has also caused poor results. The adverse effects of dense ground and brush cover on the survival and growth of many conifers and the significance of erosion (1) and topsoil thickness have sometimes been ignored.

SELECT SPECIES AND SOURCES ADAPTED TO THE LOCALITY

On the other hand, be sure to choose a species that has been proved to be adapted to the local climate. Seedlings planted should be of a species native to the area or one that has grown successfully in nearby plantations. It is best, in fact, if the seed used to produce the planting stock is from local trees. This is because for many species local races or ecotypes have developed that are specially adapted to the specific combination of day-length, temperature, and precipitation that prevails in a particular vicinity.

Selection of sources adapted to local temperature extremes, especially cold, is important. Frost-caused dieback in a 3-year-old yellow-poplar plantation in Ohio was more than twice as extensive on trees of southern origin than on those of local or more northern origin (47). Similarly, of six different geographic sources of loblolly pine planted in a study in southern Illinois, there was much less frost-kill in trees from the northern sources (Maryland, Virginia, and Arkansas) than the three southern sources (North Carolina, South Carolina, and Mississippi) (174). And Meuli and Shirley (92) reported more drought resistance of green ash seedlings from the northwestern parts of the prairie-plains region than from the southern and southeastern parts.

Although loblolly pine is not native to the Central States, so many successful plantings of this species have been established north of its natural range that it has been listed as suitable to many sites in the southern parts of the region (5). It is susceptible to severe glaze damage and winterkill, but if owners accept this risk there is a good chance of higher yields than from other species. Loblolly pine planting stock should be obtained from seed sources located at the northernmost parts of its natural range.

New varieties and hybrids are constantly being discovered or developed; some of these are superior to planting stock currently used (69). For example, two natural hybrid poplars, one exhibiting rapid growth, another possessing a wavy grain desirable for veneer stock, have recently been discovered in Iowa (77). And hybrids of pitch-loblolly and shortleaf-loblolly pines appear promising (40). A review of recent literature or consultations with workers at forest and agricultural experiment stations should be made before choosing new hybrids and varieties for large-scale plantings.

SELECT SPECIES AND SOURCES SUITABLE FOR PRODUCT DESIRED

Most forest plantations in the Central States are established to produce some kind of commercial product. Ranging from Christmas trees to sawtimber, the products desired of course determine the selection of species to be planted.

Species differ greatly in their suitability for specific uses. Criteria for considering the relative merits of each species for various uses are too numerous to discuss in this bulletin. A number of publications on this subject are available (142) (85) (155). Lists of species commonly planted in the Central States, together with the products for which they are suitable, are given here, however (tables 4 and 5). The lists also give some of the most important factors to consider in choosing species for planting. These include an estimate of the number of years required to grow the product desired, the potential quality, and critical production factors that often affect the success or failure of a plantation.

In recent years selection of trees for planting has become more and more refined. Today specific strains and sources of certain species may be selected not only for their adaptability to given sites, as previously discussed, but also for their superior product characteristics.

Some trees of the same species but from different sources may differ widely in rate of growth, resistance to disease and insects, stem and crown form, color of foliage, branchiness, and wood quality. For example the marked differences in stem form, foliage color, and growth rate of Scotch pine from various parts of Europe are well known. Moreover, Minckler and Ryker (100) have reported striking differences in foliage color, crown form, and growth of redcedar from 8 geographic sources in experimental plantings in southern Illinois.

Table 4.--Potential products from coniferous plantations in the Central States[1]

Species and chief uses	Years to produce	Quality	Critical production factors[2]
Juniper, Rocky Mountain:			
cover (and nurse crop for other species)	10-15	Fair	Grows very slowly
Larch, European:			
logs, (lumber, poles, farm timber)	50-80	Fair	---
Pine, Austrian:			
Christmas trees	8-12	Fair	Form, color
posts	15-25	Fair	---
logs (lumber, farm timber)	70-90	Fair	Early stagnation limits yield
Pine, jack:			
Christmas trees	5-8	Poor to fair	Form, color important
pulpwood and posts	20-30	Fair to good	---
Pine, loblolly:			
pulpwood and posts	15-30	Good	Glaze, frost injury, seed source
poles and piling	35-50	Good	Glaze, frost injury, seed source
logs (lumber, boxes, etc)	50-60	Good	Glaze, frost injury, seed source
Pine, pitch:			
pulpwood and posts	20-30	Good	---
logs	60-80	Fair to poor	Heavy branching habit
Pine, ponderosa:			
Christmas trees	8-12	Fair	---
posts	20-30	Fair	---
logs (lumber, boxes, etc)	70-90	Fair	Needle-cast fungus serious
Pine, red:			
Christmas trees	5-8	Fair to good	European pine shoot moth
pulpwood, mine props & posts	25-35	Good	European pine shoot moth
logs (lumber, boxes, crates)	70-80	Fair	European pine shoot moth

Table 4.--Potential products from coniferous plantations in the Central States[1] (con.)

Species and chief uses	Years to produce	Quality	Critical production factors[2]
Pine, Scotch:			
Christmas trees	5-8	Good to excellent	Color, form (seed sources very important)
pulpwood and posts	25-35	Fair	---
logs (lumber, boxes, etc.)	70-80	Poor to fair	Form, branchiness (seed source very important)
Pine, shortleaf:			
pulpwood and posts	20-30	Good	Seed source
poles and piling	40-50	Good	Tip moth
logs (lumber, boxes, etc.)	60-70	Good	Tip moth
Pine, eastern white:			
Christmas trees	7-10	Fair to good	---
pulpwood and posts	25-35	Fair	Branchiness
logs (lumber, boxes, etc.)	70-80	Good	Branchiness
Pine, Virginia:			
Christmas trees	5-10	Poor	Color, form
pulpwood, props and posts	15-25	Good	Branchiness
Redcedar, eastern:			
Christmas trees	8-15	Poor to fair	Color, form
posts	25-35	Good	---
logs	70-80	Good	---
Spruce, Norway:			
Christmas trees	8-12	Good	---
logs	60-80	Fair	Site requirements

[1]The list of species plantable for Christmas trees is not complete; only those that can also be planted for wood products, or that can be mixed with species suitable for wood products, are listed.

[2]Special conditions, related generally to the need for a careful selection of stock from specific seed sources, a careful evaluation of the site, or measures to control insects or diseases.

Table 5.--Potential products from hardwood plantations in the Central States

Species and chief uses	Years to produce	Quality	Critical production factors[1]
Ash, green and white:			
pulpwood	30-50	Fair	Site requirements
logs (handle stock, lumber)	50-70	Good	Site requirements
Catalpa:			
posts	15-25	Fair	Form, branchiness
Cottonwood:			
pulpwood	10-20	Good	Fiber length
logs (boxes, crates, lumber, veneer)	30-50	Good	Branchiness, growth rate
Hackberry:			
logs (boxes, crates, furniture, mill-work)	50-70	Fair	Growth rate
Locust, black:			
posts, mine props	7-15	Good	Locust borer
Maple, silver:			
pulpwood	20-30	Good	Multiple stems
Oak, northern red and bur:			
posts, mine props	20-30	Good	Site requirements
logs	60-80	Good	Site requirements
Osage-orange:			
posts and props	15-30	Good	---
Sweetgum:			
pulpwood, posts	20-30	Good	Site requirements
logs (lumber, veneer, etc.)	60-80	Good	Site requirements
Sycamore:			
pulpwood, props	20-30	Good	Site requirements
logs (lumber, boxes, etc.)	60-80	Good	Site requirements
Walnut, black:			
logs (lumber, etc.)	60-80	Good	Site requirements
Yellow-poplar			
pulpwood, props	20-30	Good	
logs (lumber, veneer, etc.)	50-70	Good	Site requirements

[1]Special conditions, related generally to the need for a careful selection of stock from specific seed sources, a careful evaluation of the site, or measures to control insects or diseases.

Wide variation is common in branchiness, taper, crook, and vigor among trees in stands. Probably these variations in trees growing in the same environment are at least in part inherited so that trees grown from seed would tend to have the same characteristics of branching habit, form, and growth rate as their parents. It seems desirable, therefore, to collect seed from trees that have the same qualities as those wanted in the offspring. Recent reports indicate that many wood properties affecting suitability for certain products are also inherited (102). These properties include such things as the length of wood fibers, wood density, the proportion of summerwood to spring wood in the annual rings, and fibril angles, all of which affect strength, shrinkage or warpage, and pulp quality and yield. There is some evidence to show that it is possible, for example, to select cottonwood for planting that will produce pulpwood with a high proportion of long fibers (16). These factors, when known, should be considered in the choice of cuttings or seedlings for planting.

ESTABLISHING THE PLANTATION

After species for planting have been selected the planting job itself must be carefully planned. How should the ground be prepared? Where is the stock to be obtained, and what about its quality? When should the trees be planted and how far apart? Should they be planted in pure blocks or in mixtures? What methods of planting should be used, and under what conditions can seed be used instead of seedlings? Success or failure of the enterprise will hinge primarily on the answers to these questions.

PREPARING THE SITE FOR PLANTING

On many sites no ground preparation is needed; on some sites it boosts survival and growth; and on others it is an absolute necessity. Ground preparation is often costly; a study of the need for it is therefore an important part of planning a tree-planting project.

To survive and grow, a planted tree needs light and certain mineral elements from the soil (10). There must also be sufficient moisture in the soil to hold these elements in solution (68) (67) and to maintain growth processes. And finally soil and air temperatures, by their effects on evaporation and water loss of trees (transpiration), also influence survival and growth of planted trees. Three of these important site factors--soil moisture, light, and temperature--can be manipulated to a certain extent by controlling vegetation. The degree of control needed is governed largely by local climate, soil properties, topography, vegetation density, and the species selected for planting (176) (177).

Although site preparation is needed mainly to reduce competition, it is also sometimes needed to control injurious rodents, insects, and diseases. Removing heavy grass and brush cover, for example, helps reduce population of mice and rabbits (66); and the severity of blister rust, a serious disease of white pine, can be reduced by removing the alternate hosts--gooseberries and currants--from the proposed planting site and vicinity.

In general, when it appears that adverse light (and temperature) or soil moisture conditions will limit survival and growth of planted trees, some form of site treatment--before or soon after planting--is desirable. Although usually only one of these factors is limiting, both of them may combine to result in more serious effects. As examples, two experiments in the Missouri Ozarks can be cited: in one, thinned shortleaf pine stands with hardwood understories removed grew much faster than similar stands where the hardwood understory was not removed. In the other (74) (21), planted shortleaf pine released by removing the hardwood overstory grew faster than those that were not released, even though both areas supported a rather dense hardwood undergrowth. In these examples both light and available soil moisture obviously affected tree growth. Zahner has reported similar results in pine stands of Arkansas (181).

A light overstory on the other hand, may tend to increase survival on sites where transpiration of the planted trees may be excessive. The most common sites of this kind in the Central States are those in western Iowa being invaded naturally by hardwoods. In the early stages of this succession the scattered trees and shrubs protect the interplanted trees from wind and partially shade them. An experiment conducted in Wisconsin illustrates the benefits of partial shade (139): first-year survival of jack and red pines under a light aspen overstory on a sandy site was 30 to 40 percent higher than on an adjacent open, sandy site. Although soil moisture during the growing season under the aspen stand was a little lower than that in the open stand, this was more than offset by the lower transpiration rate of the planted pine.

In direct-seeding experiments Phares and Liming (113) obtained better germination and first-summer survival of shortleaf pine in the Missouri Ozarks when the overstory was girdled than when the overstory had been clear-cut. The partial shade afforded by the slowly dying girdled trees evidently provided some protection from high summer temperatures and dry winds.

On some bottomland sites too much free water in the soil may be the limiting factor. Here drainage may be desirable to improve growing conditions.

In general, some form of site preparation for planting will always be needed for planting in Iowa (72), the northern half of Missouri and Illinois, the northern third of Indiana, and the northwestern part of Ohio. In these areas poor distribution of summer rainfall and highly productive soils that support luxuriant vegetation combine to make both light and soil moisture conditions critical. In the other parts of the Central States where the amount and distribution of precipitation are better, soil moisture is seldom a problem; here the primary concern is the density of vegetation. Site preparation is seldom needed on the typical nonstocked abandoned fields (90) (163) (fig. 4). It is needed, however, in bottomlands and on good nonstocked farmland where there is a heavy, continuous sod or dense weed and shrub growth (fig. 15).

Figure 15.--Rank growth of grasses and weeds on open, nonstocked lands such as this prairie site in Iowa, means some form of ground preparation is needed before planting, such as plowing or the use of soil sterilants. During the first few growing seasons care must be taken to keep the planted trees from being overtopped, by periodic mowing or the use of chemicals.

On cutover and poorly stocked land, site preparation before or immediately after planting is imperative (fig. 13c); in fact, planting on this land should not be considered unless the owner is willing and able to control overtopping vegetation as often as it is needed.

METHODS OF SITE PREPARATION

Site preparation for tree planting is done by mechanical or chemical methods depending upon the complexity and size of the operation, types of equipment available, character of the soil, and type of cover (166).

Mechanical

Plowing

In heavy sod or dense grassland, plowing is the most practical ground-preparation method. Drawn by animal or tractor, most farm plows can be used to prepare ground for tree planting. On large-scale operations where purchase of equipment is necessary, heavy plows of the middle-buster type, throwing the slice on both sides of the furrow, are desirable. Except for poorly drained sites, shallow, wide furrows, are best; single- or double-bottomed plows may be used. On slopes where gullying may occur, plowing should be done on the contours with furrow slices on the down-hill side. Trees are usually planted in the bottom of the furrow; on wet bottom-land sites, however, trees should be planted on the furrow slice. Plowing should be done several months before planting. Because of excessive frost-heaving in furrows, especially in the fine-textured soils, spring planting is advisable. Sometimes the entire area to be planted is plowed or disked, especially in the prairie sections of the Central States. This of course greatly increases ground preparation costs.

Furrowing has some disadvantages (126). It roughens the land surface, making walking difficult and hampering the use of some machines needed to care for the plantation. Furrows are also favorite runways for rodents and livestock that may damage the trees.

Scalping

Scalping is done by scraping away heavy surface vegetation from spots 1 to 2 feet square, usually in conjunction with the planting operation itself. Trees are planted in the center of the spot. Scalping, done by hand with hoe or mattock, is tedious and expensive and the results are usually not as effective as other methods that might be used. It should be done only where other site preparation measures are impracticable.

Ripping and Subsoiling

Ripping and subsoiling are seldom warranted for tree planting, although in some cases they may improve site conditions somewhat by loosening impervious hardpans. The few studies conducted to date indicate little benefit from ripping (89).

Disking

Although disking has limited value in tree planting, there are situations when it is warranted. One disking is not enough; it usually results in increasing the density of the vegetation. On open, nonstocked land, especially in the prairie grassland areas, disking should be used to prepare the ground for planting only when it is definitely planned to cultivate the land after planting (see page 47). On poorly stocked land it may be used to prepare the site for direct seeding (see page 104) as well as for planting. Disking may be done in narrow strips, with the trees planted in the middle of the strips, or the entire planting area may be disked. Heavy disks, equipped with hydraulically mounted, rubber-tired wheels to permit easy turning on small areas, are most adaptable to conditions in the region (fig. 16). On light to moderately gullied land the

Figure 16.--Heavy disk, especially adapted to bushy areas and heavy ground cover. Rubber-tired wheels hydraulically mounted, permit raising of disk for easy maneuvering.

disk can also be used to grade surfaces to permit machine planting (fig. 17).

Figure 17.--The disk can also be used to grade light to moderately gullied land (a), to permit machine planting (b).

Felling and Girdling

Cutting brush and felling or girdling young hardwoods, without the use of chemicals, invariably result in vigorous resprouting (31). Although one treatment may be adequate for good initial survival, repeated cuttings after planting are always needed to maintain satisfactory survival and growth. Brush can be cut with brush hooks, brush scythes, axes, or machetes. The trees may be girdled (51) by cutting a deep notch completely around the tree at a convenient height. The "Little Beaver" (fig. 18) is a useful tool

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Figure 18.--The "Little Beaver" is a useful tool for girdling trees.

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for girdling; sometimes, however, if chemicals are not applied, the girdle made by this machine is "bridged over" with new growth. For best results, all cutting and girdling should be supplemented by chemical treatment on cut surfaces (88).

Clearing and Grading

Clearing and grading land with heavy machinery is expensive and should be done only when other methods are impracticable. Some of this is being done by large companies on brushy old fields and on extensive bottomlands for the planting of cottonwood, hybrid poplars, sweetgum, and several other species. One example of a site where clearing and grading appear necessary is an old field that has been taken over by dense thickets of thorny crab apple; another is an area supporting jungle-like rhododendron. These thickets would still be impenetrable by planting crews even if the plants had been killed by chemicals. On these sites tractors with root-rake attachments (fig. 19) should be used to gouge out strips

Figure 19.--The root-rake (a), attached to front of a tractor is an effective tool for clearing brush and tree cover, (b) for planting. Also, by removing all except the two outermost teeth, the rake can ~~also~~ be used to scarify two strips simultaneously for direct seeding old fields.

on the contour and pile the debris in windrows along each side of the strip. Although not necessary, the windrows may be packed with a tractor and burned. The burning, if attempted, should be done before the trees are planted. Or, if a "Bush Hog" is available the debris may be converted to chips.

Land severely gullied (fig. 20) may need some grading before

Figure 20.--Severely gullied land may need some grading before planting, especially if planting machines are to be used.

tree planting. The grading should be done on the contour, creating a series of terraces rather than long, smooth slopes. Stabilization with grass or mechanical structures might also be needed before planting on some actively eroding, severely gullied land.

Chemical Control of Vegetation

Great strides have been made during the past two decades in developing chemicals to eliminate or reduce unwanted vegetation. Costs are continually decreasing so that the use of chemicals is often the most economical as well as the most effective means to prepare sites for planting (146) (130). In practice, the chemicals are applied to the leaves of plants (foliage sprays), to the base of stems (basal treatments), to wounds created by notching or girdling, to stumps, and to the soil (134) (3).

Control of vegetation by the use of chemicals does not always mean that the treated plants are killed (86). Some of the best chemicals now available kill only tops or crowns but resprouting from the roots may be weakened or delayed enough to allow planted trees to become established and overtop subsequent competing vegetation. Sometimes one or more additional applications are needed.

Chemicals to Use

Chemicals used in vegetation control are of two general types (140), (175), based on their mode of action: (1) the plant hormone or growth regulator type that gains entry through leaf, stem, or roots, and disrupts normal growth processes of the plant. The most common chemicals of this type are 2,4,-D, 2,4,5-T, MCP, and propionic compounds, such as "Silvex," "Kuron," and amitrol (amino triazole). (2) The contact type that is toxic to plants. Water-soluble contact chemicals such as ammate, arsenical compounds, and monuron (CMU) are translocated from one part of the plant to another. Others, such as sodium chlorate, the dinitrophenols, TCA, and some oils, kill plants by contact alone even though not readily translocated to various parts of the plant. A list of the susceptibility of common woody species to herbicides has been published (154).

Some chemicals are nonselective and can be used to control many species of plants while others are so selective that they can be used for a single species or a small number of species only. The effectiveness of all chemicals depends on many things, the most important of which are the species, season (133) and method of application; dosage (61); weather; size and age of tree; and kinds of diluent used (such as water, oil, or kerosene). In using the chemicals recommended for various types of vegetation control the specific instructions relating to dosage, methods of mixing, and safety precautions should be followed (table 6). The chemicals listed in the table are considered best for each purpose at the time these recommendations were prepared. There have been so many new herbicides developed in recent years that many of the old standbys are becoming obsolete. For this reason, readers may wish to contact their local service forester, county agricultural agent, or State Agricultural Experiment Station before starting large-scale treatments.

Table 6.--Chemicals that can be used to control vegetation for tree planting

FOR TREES MORE THAN FOUR INCHES IN DIAMETER AT BREAST HEIGHT

Method of application	Chemical to use	Dosages, formulations and seasons of application
For upland hardwoods: Aerial sprays	2,4,5-T or 2,4,5-TP (Silvex) in oil	2 lbs. acid and 5 gals. fuel oil per acre. (Late spring to mid-summer)
Frills, notches, girdles, or stumps	2,4,5-T in oil	8 lbs. ahg (acid equivalent per 100 gals) (any time)
	Ammate crystals	1 tbsp. per frill or notch, or 1 tbsp. per 2 inches of diameter of a stump or girdle. (Any time)
For sourwood: Frills, notches, girdles, or stumps	Ammate crystals	1 tbsp. per frill or per 1/2" diameter breast high (any time)
For bottomland hardwoods: Aerial sprays	2,4D/2, 4,5-T (brush killer) in oil	2 lbs. acid equivalent in 8 gals. emulsion per acre, two or more sprays probably needed. (Late spring to midsummer)

FOR TREES LESS THAN FOUR INCHES IN DIAMETER AT BREAST HEIGHT

For upland hardwoods: Aerial sprays	2,4,5-T or 2,4,5-TP (Silvex) in oil	2 lbs. acid and 5 gals. fuel oil per acre. (Late spring to mid-summer)
Basal sprays and stumps	2,4,5-T (ester form) in oil or kerosene	12-16 lbs. ahg (acid equivalent per 100 gals.) or 2 pts. (4 lbs. acid per gal. concentrate) to 5 gals. kerosene or fuel oil. (Any time)
Stumps	Ammate crystals	1 tbsp. per inch of diameter of stump. (Any time)
For red maple: Basal spray	2,4,5-T in oil	20 lbs. ahg. (Any time)
For sourwood: Stumps	Ammate crystals	1 tbsp. per 2" diameter of stump. (Any time)

Table 6.--Chemicals that can be used to control vegetation for tree planting (con.)

FOR BRUSH (Tree seedlings, shrubs, vines, etc.)

Method of application	Chemical to use	Dosages, formulations and seasons of application
In upland hardwoods: Foliage spray	2,4,5-T in water	In garden-type sprayers: 1 fluid ounce (4 lbs. acid per gal.) in 1 gal. water. Power-sprayers, back-pack sprayers, and mist blowers 2 lbs. ahg. in water. (Late spring to midsummer)
For rhododendron: Stumps	2,4,5-T in oil	20 lbs. ahg (Any time)
For laurel: Basal spray or stumps	2,4,5-T in oil	20 lbs. ahg (Any time)
For honeysuckle: Foliage spray	Amitrol (Amino triazole) in water	10 lbs. per acre of 50 percent amino triazole in 125 gals. water. Early in summer; repeat later in summer or following spring after foliage appears, using a lower volume of same concentration (19)
	2,4D and 2,4,5-T in water (Niagara brush killer), 2:1 ratio	4 gals. (2 lbs. acid equivalent per gal. concentrate) in 250 gals. water per acre. Repeat later when sprouting resumes, using lower volume of same concentration. (Early spring and later in summer (2 applications))
FOR GROUND COVER (Grasses, weeds, etc.)		
For grasses: Soil treatments	Simazine	Follow directions of manufacturer, or consult local agricultural or forestry agencies. (Early in spring)
For broadleaf weeds: Foliage spray	2,4D in oil (Ester form) or 2,4D in water (Amino form)	1 to 2 lbs. per acre in 10 to 20 gals. (Two treatments, early summer and midsummer).

Stem Treatments

To kill trees larger than 4 inches in diameter it is best to apply chemicals in girdles such as those made by the "Little Beaver," or in frills or notches cut by an ax. Make these wounds as close to the ground as possible. Any one of a number of chemicals can be used, depending upon the species, method, and season of application (table 6). Solutions of 2,4,5-T or 2,4,5-TP, in oil or kerosene, are the chemicals most commonly used in stem treatments; 2,4-D, alone or in mixture with 2,4,5-T, is also frequently used. Apply liquids liberally, filling frills and girdles to overflowing. Ammate crystals can also be applied to frills, using about a tablespoonful for every 4 inches of circumference (178).

For trees smaller than 4 inches in diameter, basal sprays without girdles or frills are effective. For good results, thoroughly soak the root collar and stem just above the root collar. A greater dosage of chemical than that prescribed for larger trees is needed.

Stump Treatments

Although basal sprays are usually more effective, trees less than 4 inches in diameter can also be felled and chemicals applied to the stumps. Cutting trees to control vegetation is not recommended, unless the logs are to be sold or used. Cut V-shaped stumps and apply liberally the same solution or crystals suggested for stem treatments. Stumps of larger trees felled in previous logging operations can be treated in the same manner. Chemicals should be applied as soon after cutting as possible. Stumps larger than 10 inches may not need treatment. On bottomlands and good upland sites, however, larger stumps may sprout prolifically.

Foliage Sprays

Foliage spraying is the most common method of using chemicals to control tree seedlings, brush, grasses, and weeds (87). Sprays must be applied after leaves have attained full size but before they turn color in the fall. Late spring and early summer are the best and often the only seasons for effective foliage spraying. Foliage should be thoroughly drenched. For some species or groups of species one chemical may be most effective, while for another species or group of species another chemical may be best (table 6). Good top-kill is generally obtained, but sprouting from roots usually occurs 1 to 2 years after treatment.

Various types of pressure tanks and back-pack pumps can be used in applying foliage sprays. Motorized spray equipment such as the mist blower, mounted on trucks or towed by animal or tractor has recently come into wide use on large-scale operations where topography permits (fig. 21). On small areas the back-pack mist-

Figure 21.--Mist blower, used here to apply insecticides on established plantation, is also effective machine to make foliar application for vegetation control before planting.

blower is an effective tool to use (141).

Aerial Spraying

Aerial spraying is fast becoming the most practicable method for large-scale vegetation control (fig. 22). It is especially

Figure 22.--Airplane spraying of chemicals is fast becoming the most practicable method of large-scale vegetation control.

effective in removing large trees where on-the-ground foliage sprays or stem treatments are impractical or too expensive. The use of the airplane in agriculture for seeding and for the control of insects, diseases, and weeds has become so widespread that in every state there are firms that do contract spraying. State aviation boards usually have a list of reputable aerial-spraying firms.

Before deciding in favor of aerial spraying however, the landowner should consider a number of pertinent factors. First, of course, is the cost in comparison with ground control methods. Costs will vary with the size of the job. Airplane spraying low-grade hardwood stands in Missouri in 1957, for example cost $7.75 per acre on a 40-acre tract and $4.92 per acre for 800 acres (124). A comparable release by hand methods would have cost from $12.50 to $25.00 per acre.

Another factor to consider is the possible damage to vegetation adjacent to the area to be sprayed. The amount of drift varies with wind velocity, type of plane used, altitude of the plane, and kind of chemical used. In one operation drift damage in a 5- to 10-mile wind extended for 200 yards to the leeward side of the area sprayed (81). On a calm day, drift damage extended no more than 50 yards in the same direction. Recent use of invert emulsions has resulted in still less danger from drift damage.

Helicopters, though more expensive, are better for spraying than airplanes, especially on rough terrain and for spraying small areas. They can generally spray at much lower altitudes than planes.

Before spraying commences the boundaries of the area to be sprayed should be conspicuously marked and visible from the air. Yellow or orange flags, balloons, or cloth markings on the ground or in trees are commonly used to mark the strips to be sprayed. The best way to mark the boundaries, however, is to apply chemicals in a basal spray or in frills on dominant trees along the boundary 2 to 5 weeks before aerial spraying. Foliage of trees thus treated will turn brown and form a line easily visible from the air.

Soil Treatments

The newest development in the chemical control of vegetation is treatment of the soil. The chemicals, some of which are sterilants, are applied in granular, pellet, or spray form in the spring, before the weeds to be controlled emerge. So new is this development that only experimental results are available. The trade names of some of these chemicals are Simazine (fig. 23) (123), Dowpon plus

Figure 23.--Simazine, a soil sterilant, applied in granular form around this planted white pine, effectively reduced grass growth without damaging the tree.

2,4-D, and Garlon. Application of some of these, and perhaps others to come, will no doubt prove to be the most practicable way to control dense vegetation of grasses, weeds, and shrubs. Some planting specialists have ingeniously added tanks and spreaders on planting machines so that chemicals can be applied in strips or spots at the same time trees are planted (56). Landowners should review current literature on these developments and consult local agricultural and forestry services in selecting and applying these new chemicals.

Mixing Chemicals and Diluents

Except where ammate crystals or where pellets and granules of soil sterilants are specified, the chemicals recommended for vegetation control (table 6) are diluted with various quantities of oil, kerosene, or water. The choice of diluent and the concentration of the chemical vary according to the chemical used, the species to be treated, and method of application (115) (116). Where oils are specified, the lighter fuel oils or diesel oils should be used, not heavy crankcase oil.

Commercial preparations of herbicides are usually available in acid, salt, or ester forms. If water is used as the diluent, the salt forms should be used; if oils are used, the esters are better. To minimize damage from drift, the low-volatile esters are recommended. Where a choice is possible, the ester form is preferred as in general it will give more effective control than the acid or salt forms.

Containers of commercial preparations nearly always bear labels specifying the "acid equivalent" of its contents in pounds per unit volume. If the acid equivalent is 2 pounds per gallon for example, and you desire a spray with 4 pounds of acid per 100 gallons of diluent, you would use 2 gallons of the concentrate (table 7).

Table 7.--Amount of herbicide to use for sprays of different concentrations[1]

When acid equivalent of herbicide is--	and required concentration of spray in pounds of acid per 100 gallons (ahg) is--						
	2	4	6	8	12	16	20
	use gallons of herbicide shown						
2.00 lbs./gal.	1.0	2.0	3.0	4.0	6.0	8.0	10.0
3.00 lbs./gal.	.7	1.3	2.0	2.7	4.0	5.3	6.7
3.34 lbs./gal.	.6	1.2	1.8	2.4	3.6	4.8	6.0
4.00 lbs./gal.	.5	1.0	1.5	2.0	3.0	4.0	5.0

[1] Taken from Station Paper No. 41, Lake States Forest Experiment Station, by Paul O. Rudolf and Richard F. Watt (128).

The diluent and concentrate should be thoroughly mixed, and kept thoroughly mixed while spraying. The amount of herbicide actually sprayed per acre will depend as much on the type of spray equipment and speed of operation as the concentration of the herbicide. Before beginning large-scale operations therefore, run a trial on small, measured areas to be sure the appropriate dosages are obtained.

Safety Precautions

Some of the chemicals used in the control of vegetation are poisonous to people or flammable. Be sure to read the manufacturer's directions for transportation, storage, and use of the chemical, as well as the antidote or first aid instructions in case of accident. Use good "safety sense" in handling chemicals. Remember:

1. Keep safety equipment, first aid kits, extinguishers, and antidotes readily available.

2. Label all containers of chemicals.

3. Use rubber gloves, goggles, aprons, and face-masks whenever they are needed to assure proper protection.

4. Read and follow the directions of the manufacturer in the storage, care, and use of chemicals.

WHERE TO GET TREES FOR PLANTING

The best place to get stock for planting is from the state forest tree nurseries. County agricultural agents, local foresters, and employees of the U.S. Soil Conservation Service are always glad to help file applications for planting stock. Or you can write directly to the state agencies listed below for application blanks, prices, and shipping instructions:

State	Name and Address
Illinois	State Division of Forestry, Dept. of Conservation, 106 State Office Bldg., 400 S. Spring St. Springfield
Indiana	Division of Forestry, State Dept. of Conservation, Indianapolis
Iowa	State Forester, Division of Lands and Waters, Iowa Conservation Commission, East 7th and Court Sts., Des Moines
Kentucky	Division of Forestry, Dept. of Conservation, New Capitol Annex, Frankfort
Missouri	Forestry Division, Missouri Conservation Commission, Monroe Bldg., Jefferson City
Ohio	Division of Forestry, Dept. of Natural Resources, 751 Northwest Blvd., Columbus 8

It is wise to order stock about 6 months in advance of planting time to assure a wide choice of species, sources, and ages of stock.

For direct seeding, or when planning for several years in the future, it may be possible to specify that seed be collected from specific trees, especially if good sources are available locally. Seeds and planting stock can also be bought from commercial seed dealers and nurserymen. An up-to-date list of commercial dealers can be obtained by writing to the Forest Service, U.S. Department of Agriculture, Washington 25, D. C.

Unless other sources of known quality are available, the best way to get cottonwood cuttings is to make them from trees of the desired quality near the planting site.

QUALITY OF PLANTING STOCK

The success or failure of a plantation depends to a great degree upon the quality of stock used. Because the development of planting stock varies greatly among nurseries and from season to season in the same nursery, age alone is not an indicator of stock quality. Moreover, plantable stock of most of the species planted is produced in one growing season.

Stock quality should be judged mainly on the basis of size and balance. Stem diameter and length and weight of roots in relation to length and weight of tops are generally considered the most practicable criteria for judging stock quality. Root and top pruning, common practices in nurseries to adapt seedling size to various methods of planting, also affect stock quality.

A few specific studies have been made to determine grading standards in the region. Chapman (25) in studying shortleaf pine found that greater stem diameters meant better survival. Similarly, yellow-poplar survival was greater the larger the stem diameter when seedlings ranged from 3/20 to 6/20 inch (76). Survival declined in seedlings larger than 6/20 inch when roots were pruned to 8 inches.

Top pruning has no significant effect on survival of yellow-poplar or, apparently, most other hardwoods. Packing and shipping are cheaper if hardwood seedlings are top pruned just after lifting in the nursery. And more top-pruned than not-pruned trees can be carried in a planting tray.

In most planting, roots are pruned to standard lengths, depending upon the method of planting to be used. Pruning is sometimes done to maximum lengths of only 6 inches when planting bars or planting machines are used, 8 inches when mattocks are used, and 10 inches when long-bladed grub hoes are used. Because the balance of physiological processes is involved, the degree of root-pruning may greatly affect initial survival. Root systems of seedlings severely root pruned may not develop sufficiently before the onset of dry weather to supply water when transpiration losses are high.

To be useful, stock grading standards should be simple and easily applied. They may be used by nurserymen in classifying grades of stock available for planting, or by purchasers in specifying the quality of stock desired. Grading stock is an expensive and time-consuming job for the buyer. If it is found by random sampling that 80 percent of the stock in the nursery beds or received from a nursery meets the preferred standards, grading is unnecessary. The planting stock grades recommended (tables 8 and 9) for species commonly planted are based on specific studies and on stock measurements taken from trees planted on many experimental areas. For conifers the standards are based on stem diameters (at the ground line) and the relation of top length to root length after pruning. For shortleaf pine, for example, the minimum stem diameter recommended is 5/32 inch; if roots are pruned to 6-inch lengths, the tops should be 4 to 8 inches long. For hardwoods, the standards are based only on stem diameters; maximum stem diameters are prescribed only if roots are pruned to 8 inches or less.

Table 8.--Planting stock grades for conifers commonly planted in the Central States

Species	Stem diameter at ground line (inches)		Allowable range in lengths of tops (inches)	
	Minimum	Preferred	If roots are pruned to 6"	If roots are not pruned shorter than 8"
Shortleaf pine	5/32	7/32	4 - 8	6 - 12
Jack pine	3/32	4/32	4 - 6	6 - 12
Red pine	5/32	7/32	4 - 6	6 - 12
Eastern white pine	5/32	7/32	4 - 8	6 - 12
Pitch pine	5/32	7/32	4 - 8	6 - 12
Virginia pine	3/32	4/32	4 - 6	6 - 12
Loblolly pine	3/32	4/32	4 - 8	6 - 12
Eastern redcedar	5/32	7/32	4 - 6	6 - 12

Take a random sample of the planting stock; measure each tree in the sample, and record the total number of trees measured, the number above minimum specifications, and the number above preferred specifications.

Do not accept stock for planting if sample indicates that less than 75 percent of the trees meet minimum standards.

Grade acceptable planting stock if less than 80 percent of the trees meet the preferred standards. Discard trees not meeting minimum standards.

Acceptable stock need not be graded if more than 80 percent of the trees meet the preferred standards.

Table 9.--Planting stock grades for hardwoods commonly planted in the Central States

Species	Stem diameter at ground line (inches)		
	Minimum	Preferred	Maximum (if roots are pruned to 8" or less)
Ash, green and white	3/32	5/32	10/32
Cottonwood (seedlings)[1]	5/32	7/32	no maximum[2]
Maple, silver	5/32	7/32	10/32
Oak, bur, northern red, and chestnut	5/32	7/32	10/32
Osage-orange	4/32	5/32	8/32
Sweetgum	5/32	6/32	8/32
Sycamore	4/32	6/32	10/32
Walnut, black	8/32	10/32	10/32
Yellow-poplar	8/32	10/32	12/32

Take a random sample of the planting stock; measure each tree in the sample, and record the total number of trees measured, the number above minimum specifications, and the number above preferred specifications.

Do not accept stock for planting if sample indicates that less than 75 percent of the trees meet minimum standards.

Grade acceptable planting stock if less than 80 percent of the trees meet the preferred standards. Discard trees not meeting minimum standards.

Acceptable stock need not be graded if more than 80 percent of the trees meet the preferred standards.

[1]Cuttings of cottonwood and hybrid poplars: diameter at small end should be 1/4 to 1 inch; length 12 to 20 inches; from 1- to 2-year-old dormant stems.

[2]Because cottonwood roots readily, no maximum stem diameter is needed if roots are pruned to lengths shorter than 8 inches.

In ordering stock for tree planting it is well to specify the grades desired. This will alert the nursery superintendent to your preference and will enable him to serve you better. Most nurserymen have the facilities and personnel to do an economical grading job. The intensity of sampling necessary to determine stock quality depends on the total amount of stock and its variability. If less than 75 percent of the sampled trees meet the minimum standards, it is best to reject the stock for planting. If less than 80 percent of the trees accepted for planting meet the preferred standards, the stock should be graded, and those seedlings not meeting the minimum standards should be discarded. The percentage of usable stock in the "Preferred" grade is a good estimate of stock quality.

CARE OF PLANTING STOCK

Improper care of planting stock is often the major cause of high initial mortality. When roots of many species, particularly conifers, are exposed for only a few minutes to sunlight on warm days, the trees begin to die and cannot be revived simply by rewatering. The roots of planting stock must also be protected from freezing. Stock packed tightly in rolls or bales for more than a week without watering may be seriously injured from heating; stock packed loosely, on the other hand, may dry too rapidly unless watered frequently or stored in a moist atmosphere. It is therefore imperative to protect planting stock from exposure from the time the trees are lifted at the nursery to the time of actual planting. Adequate precautions in lifting and packing stock are taken at most public and private nurseries. The proper care of stock during periods of transit, storage, and planting, is, however, largely the responsibility of the man in charge of planting.

Transportation of Planting Stock

During transit planting stock should be protected from the sun and drying winds in open trucks or trailers, the bales or bundles should be covered completely with canvas or similar material. If these precautions are taken no watering is needed during transit periods of less than 12 hours. Shipments by railroad freight should be avoided; express shipments are permissible, but arrangements should be made in advance to remove stock from express offices and warehouses as soon as possible. Ideally, stock should be transported in an enclosed or covered truck or trailer by a driver alerted to the importance of protecting the stock, and at night when the chances of adverse exposure are minimized.

Storage of Planting Stock

Trees should be planted as soon as they are received from the nursery. Often, however, this is not possible. So precautions should be taken to protect the stock until it can be planted.

As soon as the stock is received it should be inspected; some of the bundles or crates should be opened immediately to check possible damage from heating or drying. The stock should then be watered: moisten the interiors of bales and crates, but do not soak or puddle. Do not immerse bundles of trees in water until planting time.

If trees are to be planted within a week after receiving them, they may be left in bales or crates, but should be kept in a cool, shaded, well-drained area, such as a barn, woodshed, root-cellar, or an improvised lean-to. Moisten the stock daily.

If it is necessary to hold trees more than a week before planting, it is best to keep them in cold storage. Cold-storage facilities are available in many small cities and towns where eggs and poultry are stored. Many large orchards in the Central States also have space available in cold-storage warehouses during the spring planting season. If the following precautions are taken stock can be safely held in cold storage for 4 to 5 weeks:

1. Keep temperature at about 33 to 35 degrees Fahrenheit, as constantly as possible--never higher than 40 degrees.

2. Do not stack bales or bundles of stock on top of each other; place them separately on shelves. If stock is received in two or more deliveries from the nursery, the date each bundle is placed in cold storage should be written on the shipping tag. Stock held in cold storage the longest time should be planted first.

3. Water the stock once each week; this can be facilitated by attaching a perforated metal tube to the end of a hose, and inserting the tube about halfway into the bale.

If cold-storage facilities are not available and it is necessary to keep stock for more than a week before planting, the trees should be "heeled-in"; this is done by digging V-shaped trenches in a well-drained, shady location near the planting site (fig. 24).

Figure 24.--Method of trenching and heeling-in nursery stock: A, trench is dug deep enough to accommodate roots; B, layer of trees is laid against slanting wall; and C, soil is piled and packed against tree roots, leaving trench ready for another layer of trees to be heeled-in the same way.

Trees usually come from the nursery tied in small bunches of 25 to 50 trees. Untie these bunches, lay the trees in layers 3 or 4 trees deep along the sloping side of the trench, and then pack soil around the roots. Trees may be removed from the trench as required. The trenches should be kept moist but not soaked. If necessary, most hardwood species can be left heeled-in over the winter. Coniferous stock, however, should never be left heeled-in for more than 5 or 6 weeks.

Care During Planting

During planting, trees should be carried in a bucket or planting box and roots kept moist with wet moss, excelsior, peat moss, soil, or other material. The roots of baled planting stock are usually intertwined so trees should be carefully separated before they are placed in the planting-stock container. As an extra precaution against drying, place a piece of water-soaked burlap over the material covering the roots. Keeping the roots moist with these materials is better than placing the trees in buckets of water.

The planter should constantly check the condition of the stock in the container. Careless planters, in pulling out a tree for planting, often partly pull out other trees from the container, thus exposing roots to drying winds and sun.

In large-scale plantings, where several crews are working or planting machines are used, it is good practice to assign the responsibility of packing stock in containers to one man. Properly trained, he can care for the heeling-in bed, receive stock from cold storage or the nursery, and pack stock containers properly for use by the planting crews.

PLANTING SEASONS

Planting should be done during the dormant season, that is, after the hardwood trees have lost their leaves in the fall and before new leaves start in the spring. Soil conditions should be favorable. Do not attempt to plant in frozen or snow-covered ground or when the ground is wet and "sticky." The best time for planting depends upon location within the region.

Location	When to plant
Iowa, northern Missouri, northwestern Illinois	Spring--about April 1 to May 15. Hardwoods may be planted in the fall, from September 15, to December 1, in heavy cover or coarse soils where frost heaving will be less likely to occur. Do not plant conifers in fall.
Northern Ohio and Indiana, central and northeastern Illinois	Spring--about March 15 to May 1
Southern Missouri, southern Ohio, southern Indiana, southern Illinois and Kentucky	Spring--about March 1 to April 15

Except under unusual circumstances fall planting should be avoided. Trees planted in the fall are particularly susceptible to frost-heave and winter-kill. Frost-heaving is especially serious on bare ground and on fine-textured soils such as clays, silty clays, and sandy clays. It is not likely to be serious on coarse-textured, sandy soils and on grassy sites that need no ground preparation. Winter-kill is especially serious when spindly, top-heavy planting stock is used. Sturdy, well-balanced stock is especially important if trees are planted in the fall.

SPACING

Optimum spacing for planted trees has always been a controversial subject. Lack of conclusive research and a misunderstanding of some factors that should be considered have no doubt contributed to the diversity of opinion on the number of trees per acre that should be planted. In Europe, where trees have generally been planted at closer spacing than in the United States, the trend now is toward wider spacing (42) (17).

Recent experiments in America (11) (119) (18) (120) (78) (137) have provided general information on the effects of spacing on growth and form of trees. Over a wide range of spacing (4x4 to 9x9), at least for periods 5 to 25 years after planting, trees planted at wide spacings grow faster in diameter than those planted at close spacings. On the other hand, spacing has little effect on total height of species commonly planted in the region. The total cubic volume of wood produced is generally greater in dense stands than in more open stands. But in young stands the merchantable volume is usually greater in stands with wide spacings. Logging costs per unit volume of wood decrease with increasing average tree diameter (109).

In recommending spacing for forest planting in the Central States the advantages and disadvantages of wide and close spacing were carefully considered (table 10). No spacing can be considered ideal or "optimum"; the decision must often be a compromise.

In drawing up spacing recommendations, eight factors were regarded as most important:

1. Objectives of planting.--The kind and quality of products desired should be considered. For "short-rotation crops," such as fence posts, mine props, fuel, and pulpwood, a closer spacing is necessary to get maximum utilization of the site than if "long-rotation crops," such as poles, and sawtimber, are the primary objectives. For erosion control, where wood products are a secondary or minor objective, close spacing (6x6 or 7x7) is recommended.

Table 10.--Spacing recommendations for forest planting[1] in the Central States
(Spacing in feet and number of trees per acre)

Rotation and cutting plan	Jack, shortleaf, red, loblolly, and Virginia pines		White pine		Hardwoods	
	Spacing	No. trees	Spacing	No. trees	Spacing	No. trees
Short rotation crops - posts, props, pulpwood, fuel, etc.	6 x 8 or 7 x 7	908 or 889	6 x 8 or 7 x 7	908 or 889	8 x 8 or 6 x 12	681 or 605
Long rotation crops - poles, sawtimber, etc. Commercial thinnings planned	8 x 8 to 9 x 9	681 to 538	6 x 8 or 7 x 7	908 or 889	6 x 12 to 10 x 10	605 to 436
Long rotation - no thinnings planned	9 x 9 to 10 x 10	538 to 436	8 x 8 to 9 x 9	681 to 538	8 x 12 to 10 x 10	454 to 436

[1]For erosion-control planting a close spacing is recommended--6 x 6 or 7 x 7 feet. For Christmas tree planting a 5 x 5 foot spacing is most common.

2. Thinnings.--The possibility of thinning the stands before the harvest cut is also important in deciding what spacing to use. As a general rule, no thinning should be considered unless it will pay for itself either in products removed or in increased growth of the residual stand (44). If "commercial thinnings" can be made--and this depends upon accessibility of area, markets, and species planted--a closer spacing is advisable than if thinnings cannot be made.

3. Hazards and risks.--There is always the chance that trees may be damaged or killed because of adverse site conditions, insects and diseases, windthrow, fire, or grazing. And some cultural operations may even accentuate these hazards. For example, early thinning in a shortleaf pine plantation can cause high mortality due to Fomes annosus (103) (161) (171). The spacing recommendations given here are based on (1) an expected early mortality of 20 percent due to site and weather conditions, planting stock quality, planting operations, and (2) subsequent mortality as the stand develops.

4. Growth rate and stand density.--One of the objectives of stand improvement is to maintain or accelerate growth and development of the stand by thinning. This does not mean that the rapid growth during the first decade, forming what is sometimes called "juvenile wood," must be equalled in subsequent years. Nevertheless, in extremely close spacing growth reduction, and even stagnation, may occur before commercial thinnings can be made. Maintenance of good diameter growth until trees attain merchantable size is therefore a factor to consider in the choice of spacing. Our spacing recommendations are based in part on growth data taken from yield tables in current use. Spacings given are the narrowest possible to maintain good diameter growth until the first cutting. The control of "juvenile wood" by spacing does not seem feasible. Wahlenberg (162), for example, reports that the formation of wide annual rings, largely of springwood, in the first decade of loblolly pine growth cannot be avoided by close spacing. It is quite likely that this response is typical of most of the conifers planted in the region.

5. Natural regeneration.--Unless stringent controls are used, natural invasion of hardwoods in plantations is the rule rather than the exception. These volunteers can be left as "nurse" trees, or to improve the productivity of the site, or they can be taken out as thinnings or part of the final crop. If volunteers are left, the original spacing can be wider, of course. As long as the crowns of the planted trees remain dominant, their growth will not be seriously affected by the subordinate volunteer trees (106).

6. Branching.--The possible adverse effects of spacing on branching and self-pruning may not be as great as formerly presumed. In most pine plantations wide spacing has resulted in slightly larger branches but no significant increase in the number of branches (48). And any adverse effect of wide spacing might well be offset by taking advantage of the volunteer hardwood growth (111). Close spacing, on the other hand, has not eliminated the need for pruning nor significantly reduced the cost of pruning. So, for conifers at least, choice of spacing need not be influenced one way or the other by the possibility of branching. For hardwood planting, however, the story is most likely to be different.

7. Species.--Spacing recommendations should vary by species, or groups of species, because of inherent differences in growth rate and tolerance. Until more precise information is obtained, however, all pines except white pine have been grouped together. A closer spacing is allowed for white pine than for other conifers because experience has shown that this species maintains good diameter growth at a closer spacing than most other pines planted in the region. For other conifers use spacing recommended for the group if they are less tolerant of shade than white pine; use white pine spacing if more tolerant than this species. Spacings recommended for hardwoods may seem somewhat wide. Hardwoods as a group will not maintain good diameter growth to merchantable size unless they have plenty of room. If hardwoods are planted close together, they will need at least one noncommercial thinning to maintain good growth. Extremely wide spacing results in heavy branch development on such hardwoods as oak, walnut, and sycamore. The wide spacing recommended applies to these species only when volunteer growth is allowed to develop with but not overtop the planted hardwoods. If there is no volunteer hardwood regeneration, closer spacing is advisable.

8. Planting Costs.--Planting costs naturally vary with number of trees planted per acre. So it pays to plant no more trees than are needed to meet the objectives of planting. Square spacings are most commonly used, but if machines are to be used in planting and caring for the trees, it may be best to alter this pattern to facilitate machine maneuvering. A 6x8 spacing is about equivalent to a 7x7 planting, a 10x10 spacing is about the same as an 8x12 spacing.

MIXED PLANTING

Another decision that must be made early in the planning stage is whether to plant all one species or a mixture of two or more (129). Both mixed and pure plantings have their advantages and disadvantages.

Mixed plantings are less likely to be destroyed completely by diseases or insects. There is some evidence, in this country and in Europe (17), that greater yields per acre are obtained in mixed than in pure plantings. At maturity, there may be a market for one species, none for the other.

Pure plantings on the other hand are easier to establish, maintain, and manage; they are often easier to harvest and may result in higher stumpage values. Pure plantings, moreover, are almost invariably invaded by other desirable species through natural stocking, thus minimizing the danger of complete losses through disease or insects.

If mixed plantings are desired, species should be selected with great care. First, all species must be adapted to the site. Second, the slower growing species should be tolerant of shade cast by faster growing species mixed with it. In general hardwoods are more suitable for randomly mixed plantings than pines. If the species desired do not permit random mixing, and the owner wishes to avoid the risk of large pure plantings, he may resort to block or row-group mixtures (fig. 25).

Figure 25.--Suggested methods of mixing species in plantations, when random mixtures are inadvisable.

Mixed planting of conifers and hardwoods are almost always unsatisfactory. However, on sites suitable for yellow-poplar, eastern white pine, white or green ash, and northern red oak can be randomly mixed with it. On sites suitable for black walnut the following species may be mixed with it: northern red oak, white ash, green ash, and sweetgum. If both yellow-poplar and black walnut are desired, they should be planted in small-block or row-group mixtures. On sites suitable for white pine and loblolly pine the two may be randomly mixed. Other conifers should be planted in pure stands or in blocks or row-groups.

INTERPLANTING

The word "interplanting" is here used to designate any planting on areas that are already stocked with trees. It includes "underplanting," "spot planting," "reinforcement planting," "sweetening," and if the entire overstory is removed--"conversion planting." Interplanting is done chiefly to (1) improve the stocking and composition of the existing stand, or (2) utilize the existing stand for the protection and improvement in survival and early development of planted trees (26). To be successful, the selection of species and a good understanding of their shade tolerances are important.

Interplanting to improve the stocking and composition of the existing stands is good practice on old fields and cutover land partially stocked with trees of desirable species and quality. By planting trees in all openings, or in stands with widely spaced trees, the entire area may become well stocked. No trees should be planted in spots where they would be overtopped by other trees to be left in the stand.

When interplanting is done merely to protect the planted trees until they become established, provisions should be made to remove the overstory as soon as possible. The urgency for removal will vary with species used for planting and sites. Plantings on productive sites supporting dense vegetation will need the release sooner than less productive sites. Shortleaf, jack, Virginia, and loblolly pines should be released completely during the first season of planting or as soon thereafter as possible; white pine, yellow-poplar, black walnut, and red oak should be released not later than 3 to 5 years after planting. Redcedar, sweetgum, and ash may survive up to 10 years after planting under a dense overstory, but even for these species earlier releases are desirable.

For some species and sites interplanting areas that have sparse overhead cover may be better than planting on open non-stocked sites. Scattered trees and a light overhead cover may help increase survival of interplanted trees by protecting them from drying winds, moderating soil-surface temperatures, and lowering transpiration losses during dry periods. Taller trees adjacent to planted trees also act as "nurse trees" to improve form and reduce branchiness. Light shade cast by girdled overstory trees has increased germination and first-year survival of direct-seeded shortleaf pine in the Missouri Ozarks (113). Interplanting small openings in sparsely covered tree or brush stands may also be good practice in western Iowa, where dry, searing winds and high evaporation rates are critical. In other parts of the region, interplantings of species such as yellow-poplar and white pine are usually successful in sparse stands of small, short-lived species such as sassafras, persimmon, and sumac (99). It should be borne in mind, however, that other site factors such as soil, topography, and locality, need to be considered as much on sites to be interplanted as on other sites.

PLANTING METHODS

Before 1945 nearly all of the tree planting in the United States was done by hand. Since that time, because of the scarcity and high cost of labor and the many technological advances, most trees--perhaps more than 75 percent--have been planted by machine. With the advent of large-scale machine planting came questions relating to the effects of these new techniques on the subsequent survival and growth of plantations. The results to date, however, show generally that both survival and growth of machine-planted trees are satisfactory. In a study on an old field in Ohio, where all common methods of ground preparation were used, Merz and Funk (90) reported that machine planting was not only the cheapest method used but that both the survival and growth of white pine 10 years after planting were as good or even better than for those planted by hand methods. Today the choice between hand or machine methods of planting is governed largely by size of the job and roughness of the topography, or the density and size of brush, trees, and debris.

In all methods of planting there are several precautions that must be followed:

1. Plant the tree at the right depth: slightly deeper (never higher) than its depth in the nursery; it is easy to see the old ground line on the tree.

2. Plant the tree so that the main root is straight down, not doubled or sharply bent. Trees planted with roots "U-shaped" in the ground grow poorly (52). It is better to cut off the ends of long roots than to have them doubled up.
3. Press the soil well about the roots so as to hold the tree firmly in place.
4. Plant trees in an upright position, nearly even with the general ground level, not sunk in a hole, nor (except in wet, poorly drained sites) raised on a mound.
5. Plant only one tree per spot.

Hand Planting

Hand planting is generally done (1) when planting machines are not available, (2) where the planting site is too steep, too stony, too severely gullied, too brushy, or too small to be planted by machine, and (3) where there are spots and small patches that were skipped in machine planting.

There are two general methods of hand planting: the hole (side or center) method (fig. 26) and the slit method (figs. 27 and 28).

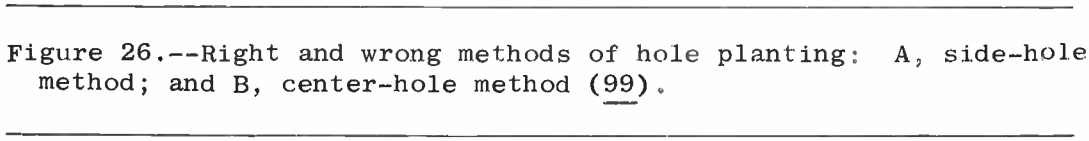

Figure 26.--Right and wrong methods of hole planting: A, side-hole method; and B, center-hole method (99).

Figure 27.--Mattock-slit method of planting.

Figure 28.--Bar-slit method of planting. (From Stauffer (136))

The side-hole method (fig. 26A) consists of digging a hole deep enough to hold the roots of the tree. One side of the hole is vertical and the tree is held against this side about 1/4 to 1/2 inch deeper than it grew in the nursery. Loose soil is then packed around the lower roots, the hole is filled, and the soil pressed with the foot. The chief precaution is to make sure that the hole is deep enough so that the roots will not be doubled or bent.

The center-hole method is similar except that the tree is placed in the center of the hole and soil packed around the roots (fig. 26B).

For the hole method use a mattock, a long straight-bladed grub hoe, or hazel hoe. A shovel or spade may also be used. This method is especially adapted to rough, rocky land and to trees with spreading root systems.

The slit method consists essentially of making a slit in the ground, inserting the tree roots, and closing the slit both top and bottom. It may be done with a mattock, grub hoe, spade, or planting bar. It is much more rapid than the hole method and is especially adapted to smooth land with light to medium soils and for trees with one long main root. Again, make sure the slit is deep enough for the roots.

The best tool for slit planting is a grub hoe or a planting bar with a blade 8 to 10 inches long. The blade should be at least as long as the roots of the trees being planted. If it is not, prune the roots (but leave at least two-thirds the original length), or plant by the hole method. Do not double up the roots. If properly done, the slit method will give as good results for tap-rooted species on the light and medium soils as the hole method. It will be much cheaper because planting goes much faster.

The planting bar is faster than the grub hoe and is used where scalping (removal of grass or other plant cover) is unnecessary or sod has been removed by plowing furrows. It is handled essentially the same way as the grub hoe. This tool may be purchased or made in the farm shop. The state forester or extension forester can supply names of manufacturers. It was developed for use in planting large acreages, and the farmer who plans to plant more than about 20 acres may save money by using it.

Machine Planting

Most planting machines consist of a rolling coulter that cuts through the ground surface, a trencher that creates a slit for inserting the tree, and packing wheels that firm the soil after planting. Many types of planting machines are on the market, and each year more will no doubt be developed. There is no single machine, however, that meets the requirements for all planting situations; and there are some situations where the use of planting machines is impracticable. Each planting machine has its advantages and disadvantages. To increase the versatility of planting machines some manufacturers have developed accessories that can be used to overcome specific difficulties for various sites and localities. In planning a tree planting job, then, the landowner should first decide whether planting machines can be used and second, select the best machine available for the job.

For small operations planting machines can be rented from most state forestry divisions, conservation groups, and some local equipment rental agencies. For large operations, especially those that continue for 2 or more years, it is advisable to purchase a machine.

Types of Planting Machines

Tree-planting machines are of three general types (125): the "floating type" (fig. 29) is attached to a tractor drawbar in

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Figure 29.--Three types of tree-planting machines in common use: (A) "floating type," (B) "semi-floating type," and (C) the "trailer type."

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such a way that the entire machine can be lifted off the ground by the hydraulic lift on the tractor. The "semi-floating type" has its front end carried by the tractor and its back end carried on wheels; it cannot be lifted by the tractor. The "trailer type" has all or nearly all its weight carried on its own wheels; this type usually has a coulter and trencher that automatically raise the machine out of the ground over logs and boulders. Each of these three types of planting machines has its advantages and disadvantages for any particular planting operation. And models of each type, constructed by different manufacturers, also vary in their adaptation to various planting situations. In making the choice of machines the following features (121), as well as comparative costs, should be considered:

1. Ease of operation.--Comfort of tree planter; ease in hitching on to tractor or lifting machine over obstacles; smooth working parts.

2. Maneuverability.--Amount of space needed to turn around; adaptability to planting small patches and corners.

3. Protection.--Devices to protect operator from brush, trees, and other obstructions.

4. Versatility.--Adaptatation to a number of different situations.

5. Construction.--Sturdiness; quality and thickness of frame, gears, other parts.

6. Stability.--Some machines tip over easier than others; the trencher is more difficult to operate smoothly on some machines than others.

7. Tractive power.--Some planting machines will need larger, more expensive tractors to pull them than others; some can be drawn by horses. Wheel tractors are faster to operate on level, cleared land than crawler tractors; the latter are better adapted to hilly and brush-covered land.

Critical Operating Factors

Experience during the past decade has revealed several operational factors that have a bearing on the use and efficiency of planting machines. Some are so critical as to prevent the use of any planting machine, while others are important factors to consider in selecting the kind of machine to be used. In some cases only alterations or slight modification of the machine to meet changing conditions from one area to another are needed. The most important of these critical operational factors are size of area, topography, character and density of cover, and soil conditions.

Size of area

On small areas (less than 5 acres) where frequent turning around will be necessary, it is better to use a floating type of machine; otherwise much of the area along the edges must be planted by hand. It is not practicable to plant areas less than 1 acre by machine.

Topography

Topography is one of the most important site factors limiting the use of tree-planting machines. Machines cannot be used effectively on steep, rough land.

When planting along the contour, the slope of the hill affects the angle of the trencher and the stability of both planting machine and tractor. Whether a tree is planted in an upright position or on a slant depends on the angle of the trencher. Machines that have three-point hitches and hydraulic cylinders controlling the trencher, or packing wheels and operator seats that can be adjusted to slope variations, are best for planting along the contours. Crawler-type tractors are better and safer than wheel tractors for planting on slopes. Depending upon type of planting machine and tractor, a safe maximum slope for contour planting is 10 to 15 percent on rough ground, 15 to 20 percent on smooth ground. (A 10-percent slope means a rise of 10 feet for 100 feet horizontal.) With the use of specially designed equipment, consisting of a self-leveling and hydraulically operated plow and planting machine, the Muskingum Conservancy District in Ohio has contour-planted slopes as steep as 50 percent.

Planting across contours (up and down slopes) can be done on steeper slopes than planting along contours and is limited mainly by tractor power. On steep slopes it is possible to plant only while proceeding downhill, but this is still cheaper and easier than hand planting. Crawler tractors or wheel tractors with half tracks should be used for planting up or down slopes. Up or downhill planting is limited to sites where no ground preparation is needed or to sites where scalping is feasible. In the latter case, a planting machine with scalpers is desirable. However, no ground preparation is needed on most of the hill plantings on old fields in the southern parts of the Central States.

Character and density of cover

On open, nonstocked land with a heavy sod cover, where no ground preparation is planned, the use of planting machines with furrowing or scalping attachments should be considered. On poorly stocked land (see page 14 for definition) the use of heavy, trailer-type planting machines is nearly always needed. If cover is dense, or if there is much debris on the ground, hand planting or the use of a "pusher plow" attached to the front of the tractor (127) (131) (122) is necessary. Machine planting is impracticable on cutover land.

Soil condition

Texture, stoniness, and moisture content of soils have an important bearing on the effectiveness of machine planting. These factors need to be considered in choosing planting machines and tractive power for large-scale planting operations. In some cases the effectiveness of machines in use can be improved by the addition of accessories or the removal of some standard parts.

On stony soils the coulters of some machines do not function properly. One operator solved this problem on an extremely stony bottomland in Illinois by removing the coulter; after the coulter was removed the "shoe" had no difficulty going through the stony soil at about the right depth. When machines are used in planting on stony soils, it is advisable to have a man follow behind the machine to dig up and hand plant those trees not properly planted by the machine; where conditions are such that many trees have to be replanted, machines should not be used.

Machine planting in wet clay is difficult. Crawler tractors generally perform best in this situation; one operator in Illinois found that a team of mules towing a trailer-type machine did a better job than a wheel-type tractor on wet bottomland soils. Most of the difficulty in machine planting wet clay soils is due to improper slits made by the trencher and packing wheels becoming clogged with mud (65). Machines with large packing wheels (12 to 15 inches in diameter) work better on these sites than those with the smaller ones. Fox (46) has improved the performance of planting machines in this situation by adding a larger auxiliary wheel to the rear of the planting machine to absorb the extra pressure when packing wheels hit soft ground; this also is helpful in coarse, sandy soils.

In general, machine planting on wet clay soils is easier on land where no ground preparation has been done than on furrowed or cultivated land. When two or more different sites are to be planted it is better to plant the coarse, sandy soils during wet weather and the fine-textured soils during dry weather. It is better to keep stock in cold storage for as long as 5 weeks until soil moisture conditions improve than to plant in wet, muddy, clay soils.

The Machine Planting Job

As much vigilance is required to get a good job of machine planting as is required for hand planting. On dry, sunny, windy days great care must be taken to see that roots of trees are kept moist. Use a soaked piece of burlap over the container from which trees are withdrawn for planting. Machine performance should be constantly checked. Measure the operating depth of the trencher frequently. Dig up a number of trees each hour to see if depth of planting and soil packing are correct.

Planting stock for machine planting must be of uniform size and high quality. Both small and large trees are hard to plant properly. All trees should, if possible, be of the "preferred grade" (see tables 8 and 9, pages 69 and 70). Hardwood seedlings may be top pruned to facilitate planting. If hand planting is also planned, use the smaller trees of acceptable grades for this job.

A 3-man crew is generally used in machine planting: a tractor operator, tree planter, and tree packer. When all three men are qualified, the men on crews switch jobs to reduce fatigue. As with all mechanical operations, daily maintenance of equipment and a ready supply of spare parts will reduce the number and duration of breakdowns.

Safety Precautions for Machine Planting

The following safety rules, adopted by the U.S. Forest Service (158) may well be considered in planning and supervising machine-tree-planting operations.

"(1) Machine shall be provided with foot guards that completely cover the bottom and sides of the feet. These guards should be checked frequently for any signs of breakage or other damage.

"(2) A heavy screen guard shall be attached to the planter, to protect the operator when planting is being done in heavy brush. The rear should be unguarded so the operator can get out quickly in an emergency.

"(3) If planting is being done in rough terrain, or in areas of logs or heavy brush, the machine that pulls the planter shall be equipped with a V-shaped blade or angle dozer.

"(4) A signal device such as a buzzer or rope-pull shall be provided for the machine operator and the tractor driver. The signal for a stop shall be definitely understood by both operators. Or a device may be installed on the planting machine to allow the machine operator to disengage the master clutch on the tractor or to release the planting machine from the tractor in case of emergency.

"(5) Operators shall wear close-fitting clothing, hard hats, and goggles or other adequate eye protection if the machine is not adequately screened.

"(6) Operators shall watch for sticks, logs, or brush that may poke up through openings in the machine.

"(7) The power unit drawing the planting machine shall be confined to limited degree turns to prevent tipping over the planting machine.

"(8) All tractors shall be equipped with upright exhaust pipes to direct exhaust gases away from tractor and planting-machine operators.

"(9) All tractor planting-machine outfits shall be equipped with a first-aid kit (snake-bite kit where appropriate), shovel, ax, and fire extinguisher. A rearview mirror should be mounted on the tractor."

DIRECT SEEDING

In the Central States region only black walnut, the oaks, and shortleaf pine should be considered for large-scale direct seeding. Best results from direct seeding can be expected on cutover and poorly stocked land, and then only if sites are suitable for the species used. Recent, but incomplete research indicates that yellow-poplar may also be direct-seeded on this kind of site.

The advantages of direct seeding are: (1) It may be much cheaper; (2) the landowner can collect his own seed, thus saving money and making sure that his trees are from local stock; (3) seeding can be done even if planting stock is unobtainable; (4) as seeding may be done in late fall, while planting is best done in the spring, the workload can be better distributed; and (5) the more natural root systems of seed plantings usually insure better trees.

Pine Seeding

Direct seeding pine has one big disadvantage. In a dry year it may be a nearly complete failure; drought is the greatest obstacle to success with direct seeding. It usually is risky business to direct-seed any of the pine species in heavy broomsedge, because in addition to drought such sites are almost always infested with mice, which eat the seeds or seedlings. Some losses from birds and rodents also occur. In general, pine seeding is most suitable on sites recently logged over, where much of the soil has been loosened up, or on areas that have been scarified by disking or by dragging a treetop over most of the area (fig. 30).

Figure 30.--Shortleaf pine direct seeded on a cutover upland hardwood site in the Missouri Ozarks. A good oak-pine stand appears to be developing.

Use about 1 pound of shortleaf pine seed and about 1 1/2 pounds of loblolly pine per acre. The seeding should be done in late fall, before January, to get best results. Recent research in the South resulted in better results when seed was treated with a bird repellent and rodenticide (84). For hand sowing, treatments consisting of 15 pounds of sublimed anthraquinone and 2 pounds of endrin per 100 pounds of seed are recommended; Latex 512R diluted with water at the ratio of 1:9 serves as a good sticker. Adding 1/2 pound of aluminum powder per 100 pounds seed will make the operation of the seeder easier. The seed can be broadcast with a "cyclone seeder"; concentrate sowing on surfaces loosened by logging, scarification, or disking.

Oak and Walnut Seeding

The essential steps in establishing oak and walnut by direct seeding are as follows:

1. Collect seed by gathering sound acorns or walnuts from the ground underneath trees. Bad acorns may be separated from good ones by dumping them all in a tub of water: the sound acorns sink and the defective ones float. Although it is not necessary to husk walnuts, they are easier to handle when this is done; when husked and dried they can also be tested for soundness by floating in water.

2. Seed in the fall any time after the seeds are collected. But if rodents are a problem, spring seeding is better. The acorns and hulled walnuts should be mixed with moist sand, peat, or a light loamy soil and left outdoors or kept humid in cold storage over winter. Acorns should not be allowed to dry out before planting. Many seeds, either walnut or oak, planted in the spring may not germinate until the following spring.

3. Make holes with a hoe, or a dibble, and insert two acorns or walnuts in a spot, several inches apart. Cover to a depth about equal to the diameter of the seed. A light mulch over the spot is beneficial but not necessary.

4. If cost is not prohibitive, better results may be obtained by covering the planted seed with screen or hardware cloth.

PLANTING POPLAR CUTTINGS

Forestation by the use of cuttings of cottonwood and poplar hybrids is often successful (83). Cottonwood cutting material can usually be made from vigorous sprout and seedling growth along streams in the same locality where the planting is planned. Handled properly, the planting can be done in this manner at a lower cost--and with better results--than with seedlings of possible distant seed origin obtained from a nursery.

The cuttings should be made during the dormant season, preferably just before planting time. Select cuttings from vigorous sprouts or seedlings; they are usually most abundant on sandbars along streams and other lowlands flooded periodically. Although stems 2 years old are permissible, it is best to make most of your cuttings from parts of the stem 1 year old. Make the cuttings from branches as well as the main stem but do not use the tips of either. Cuttings should be at least 1/4 inch in diameter, preferably from 1/2 to 1 inch. They should be at least 12 inches long, preferably 15 to 20 inches. The cuttings should be made with sharp tools, so the bark is not stripped or loosened in the operation.

If cuttings are made a long time in advance of planting, they should be tied in bundles of convenient size (25-50 cuttings) and buried in moist, well-drained sand or sawdust, outdoors. If they have to be transported long distances before planting it may be advisable to coat the tips with paraffin to prevent them from drying (147). Before planting it is advisable to soak the cuttings in water for 1 or 2 days (147).

In planting, the cutting should be set in a vertical position in the ground, with the larger end at the bottom; the smaller end should be flush with the ground surface, or not more than 2 inches above the surface. A planting rod (fig. 31), easily made

Figure 31.--Planting rods, from 1/2- to 3/4-inch iron can be easily made by your local blacksmith for planting poplar cuttings.

by a local blacksmith, is the best tool to use for planting; the cutting should extend to the bottom of the hole and should be tamped with the heel of the shoe. Areas planted with cottonwood cuttings must be cultivated at least twice during the first year and once during the second year.

USE OF WILDINGS

In many woodlands and old plantations there are openings with an overabundance of natural reproduction. Some of these "naturals," if suitable for the site to be planted, can be dug up with spades and used in planting. Care should be taken that the roots of these seedlings do not dry before planting. Stock specifications should also conform to the standards set up for nursery stock (tables 8 and 9).

CONTRACT PLANTING

Some landowners may prefer to contract all or parts of a tree-planting operation. A contract can include planting surveys, ground preparation, purchase and transportation of stock, and planting. On some small plantings, especially where the landowner and contractor know each other well, an oral agreement or a simple, written, informal memorandum of agreement will suffice. On large-scale operations, however, it is desirable to execute formal contracts with the aid of an attorney. The local county agricultural agent or public forestry and soil technicians can usually supply a list of consulting foresters or other reputable organizations that do contract planting.

The legal procedure for drawing up contracts no doubt varies somewhat in each state. There are, however, certain standardized provisions that the landowner should consider in making the contract. Some of these are obligations always assumed by the owner; others, depending upon the phases of the operation the owner wishes to contract, are obligations of the contractor. The obligations of both owner and contractor should be clearly set forth in the contract.

Obligations of the Owner

1. Payments.--Owner agrees to pay the contractor (a) a specified sum for the planting survey; (b) the cost of trees and transportation, usually at a specific rate per thousand trees; (c) the cost of ground preparation, usually at a specified rate on a per-acre basis; and (d) the cost of planting, usually at specified rates per thousand trees. Payments to be made after completion of contract, or specified amounts upon completion of each part of the contract.

2. Access. The owner agrees to provide the contractor all rights of ingress and egress to the planting site for all men, materials, and equipment necessary to perform the job contracted.

3. Planting stock and equipment.--If not included in the contract, the owner agrees to furnish the contractor the planting stock, supplies, and equipment, at a specified time, for completing the job contracted.

4. Maps and location data.-- If a planting survey is not to be included in the contract, the owner agrees to provide the contractor a sketch map showing the location of the planting area, with each area properly identified as to species to be planted, spacing, and mixture. If the owner wishes to include a planting survey in the contract, the owner agrees to furnish the contractor the legal description of the parcel of land to be surveyed for planting.

Obligations of the Contractor

1. If planting surveys are included in contract.--Contractor will make a planting survey of the parcel of land specified by the owner. The planting survey will include a site evaluation of the land for planting, delineate (a) areas in need of planting, giving acreage and location on a sketch map; (b) area in each planting-site class; (c) number of trees and species to plant on each planting site; spacing, planting methods, and mixtures to use; and (d) site preparation needed.

2. If site preparation is included in contract.--Contractor will furnish supplies and equipment needed to complete the ground preparation specified in the contract; contractor will complete the specified ground preparation work. Specification should include time work is to be done, types and methods of ground preparation, such as furrowing, disking, and the use of chemicals to control vegetation.

3. If stock purchases and deliveries are included in contract.--Contractor will obtain the quantity of stock of each species specified by the owner; stock will be of seed origin, variety, and quality specified by the owner. Stock will be delivered to planting site in good, plantable condition; owner reserves the right to inspect planting stock at destination, and to reject all trees that appear to have been damaged in transit by heating, freezing, or desiccation.

4. If planting is included in contract.--The contractor agrees to abide by the following general specification, with a tolerance factor not to exceed 10 percent:

a. Trees will be planted at spacings specified in contract.

b. Trees will be planted slightly deeper than planted in the nursery.

c. Trees shall be firmed with mineral soil packed in and around the roots, so that they cannot easily be pulled out of the ground.

d. Trees may be planted by hand or machine methods.

e. Trees must be planted in such a manner that roots will not be twisted, balled, or bent in "U" or "J" shapes.

f. Roots of planting stock must be kept moist at all times prior to and during the planting operation.

g. Except for the lengths specified, roots of trees will not be pruned or cut by the contractor.

h. Trees will be planted on the area specified by the owner.

Protective Clauses and Penalties

1. Damages.--Contractor agrees to repair, replace, or pay for damage done to any property in the performance of the contract, beyond ordinary wear and tear. In case of failure of the contractor to repair damage to property, the penalty shall be equal to the cost of having the repair done by another contractor.

2. Delays caused by owner.--The owner shall pay the contractor at the rate of a specified sum for each day's delay, for any delays in the planting operation caused by the owner, or his assignees.

3. Failure to complete planting.--In case of failure of contractor to complete by the closing date of the planting season the number of trees and areas specified in the contract, penalty shall be forfeiture of payment in the amount needed to complete the planting.

4. Arbitration.--Where differences occur between owner and contractor on the amounts of penalties to be assessed, they shall be resolved by a mutually accepted third party, who shall act as arbiter and whose decision shall be final. One-half of arbiter's fee will be paid by the owner, one-half by the contractor.

5. Survival.--The criterion for satisfactory planting will be a survival of at least 80 percent of the trees planted by June 1 of the first growing season. When the survival at this date is in dispute the decision will be vested in the arbiter.

PUBLIC AID FOR TREE PLANTING

Because of the growing need for forest products and good land use in our economy, federal, state, and some local public agencies provide some aid in forest planting on privately owned land. Public aid usually consists of furnishing planting stock at nominal prices, technical assistance, and funds to partly finance the planting operation.

All of the states in the region, financed partly by federal funds granted under the Clark-McNary Act (152), furnish planting stock at prices equal to or slightly above production costs. Although restrictions vary somewhat from one state to another, trees purchased for forest planting may not be used for landscape or ornamental purposes, nor for growing Christmas trees as the principal crop. In some states favorable tax laws may be applied to land planted to trees (170).

The Cooperative Forest Management Act of August 25, 1950 (152) authorized the Secretary of Agriculture "to cooperate with the states to enable them to provide technical services to private forest landowners." Under this act a number of farm or service foresters are located at various places in each state to advise landowners on tree-planting practices as well as forest management and timber marketing.

Financial assistance in forest planting is sometimes furnished by the Federal Government in programs designed mainly to promote good conservation practices or to control the production of farm crops. Information on this kind of assistance can be obtained from the state forester, county agricultural agent, or local Department of Agriculture representative.

EARLY CARE OF PLANTATIONS

Although plantation management is not within the scope of this publication, it is necessary from the standpoint of plantation establishment to point out the need for early care and protection. Indeed, the early care needed on certain sites and the owner's ability to perform these operations are factors to be considered before deciding whether the site should be planted. For some species and sites, plantation care is costly; on areas where it is generally needed costs range from one-third to one-half of the planting costs. On many sites little or no plantation care is needed, but on others it may well mean the difference between success and failure. A study of the need for early plantation care is therefore desirable; it should be made at the time the site is examined for planting and immediately after the planting job is completed.

Early care of plantations includes, mainly, measures to release the planted trees from competition and measures needed to protect the plantation from fire, grazing, diseases, insects, and rodents.

PLANTING RELEASE

Two kinds of plantation release are generally recognized; low release, which includes the removal or killing of such cover as weeds, grass, and brush; and high release, which refers to the removal of trees overtopping the planted trees.

Low Release

Low release is needed on those sites where low cover, such as grasses, weeds and brush, is so dense that it will seriously affect the chances of survival and good growth of the planted trees. Nearly all the planting of conifers on cutover and poorly stocked land will need some low release, at least during the first growing season. If a good preplanting release is done such fast-growing species as cottonwood and yellow-poplar, when planted on suitable sites, generally need no further release. Low release will generally be needed on open, nonstocked land where site preparation has been necessary (page 47); it will seldom be needed on the typical old fields where no site preparation was needed. Late spring or early summer is the best time to begin low release; second and succeeding releases should be made later only if needed.

On small plantations, or on large plantations where release is needed on a few scattered patches, low release can be done by hand methods, using sickles, scythes, or hoes. On larger plantations, where the cover consists mainly of grasses and weeds, mowing is perhaps the best method of low release. Large rotary mowers have been quite satisfactory for this work (fig. 32). Unless the planted

Figure 32.--Two types of rotary mowers used extensively for the control of grass and weed cover in plantations.

trees have been marked, or the land furrowed so that the location of the planted trees can be easily determined, it is important that the mowing be done before the vegetation gets so tall that the planted trees cannot be seen during the mowing operation. Control of grasses and weeds by the use of newly developed chemicals, may ultimately prove the best and cheapest low-release method, however.

On plantations located on prairie soils, where sites have been prepared by disking, low release can be done by cultivating. Equipment generally available on the farm for cultivating farm crops may be used for low release on these sites. Cultivation is also necessary on bottomland plantings of cottonwood, especially if cuttings were used for planting.

On cutover and poorly stocked land and some old fields, where low cover consists mainly of brush (briars, sumac, laurel, etc.) and tree sprouts, chemical methods of control are best (see page 52 and table 6).

High Release

To assure good survival and growth of planted seedlings, trees overtopping them must be removed; and the sooner this release is done the better (21). It is better to completely remove the overstory before planting than to delay this work until after planting. If the overstory is removed first, most plantings on cutover or poorly stocked land may not need any high release, or only a relatively cheap "mop-up" release. On good sites, where vigorous sprouting occurs, an additional release 4 to 8 years after planting may be necessary. Landowners will do well to consider the costs of these releases before attempting to plant on such sites.

Large coniferous plantations established under a partial hardwood overstory can be released best by aerial spraying, because the coniferous trees are not affected if recommended chemicals and concentrations are used. Planted hardwood seedlings, however, must be released by carefully spraying the base of each tree to be removed.

Before high release is made it is sometimes desirable to make a tally of the overstory and the planted trees. If more than 75 percent of the planted trees are not overtopped, high release is perhaps not worth the expense (fig. 33). Also, some of the

Figure 33.--Conditions under which release of planted trees is and is not needed.

trees overtopping the planted trees may be desirable species, of good form, and potentially better "final crop" trees than those that were planted. It would be foolish to remove trees of this kind. A mixture of planted and volunteer trees is often a good objective of forest management.

PROTECTION OF PLANTATIONS

Forest plantations should be protected from fire, grazing, rodents, insects, and diseases. Periodic examinations followed by quick remedial measures may prevent total loss of the plantation or reduce control costs later. If diagnosis is difficult (112), or practical control measures not known, the local service forester or county agricultural agent should be consulted. Or, send reports to the state forester or the state extension forester.

It is essential that the tree plantings be protected from fire. This can be done partly by careful handling of brush fires, grass fires, smokes, and matches. If the planting is adjacent to a road or railroad, a strip 10 to 15 feet wide should be plowed around it and kept fresh by disking as necessary. To prevent erosion, avoid, if possible, having the bare fire lanes run up and down a slope. Repeated disking and serious erosion can, however, be avoided by seeding a perpetually green crop, such as fescue or ladino clover, in the fire lanes.

Cattle, horses, sheep, or hogs can ruin a plantation by browsing, trampling, uprooting, and breaking the trees. Livestock should be kept out of plantations; the fences should be maintained permanently, as heavily grazed woodlands deteriorate rapidly and are neither good pasture nor good forest.

Measures for rodent control are generally expensive and difficult; unless severe losses are apt to occur, control measures are not warranted. Damage from mice and rabbits can be reduced by eliminating their favorite habitat--dense grass and brush--by mowing or applying herbicides. Mice populations in small plantations may be reduced by the use of poison baits, such as strychnine alkaloid or zinc phosphide (138); intensified hunting may reduce rabbit population. Small plantations may also be protected from rabbits by the use of repellents (59).

The greatest hazards to tree survival are epidemics of insect pests or diseases. The chances of loss from them can be reduced somewhat by the careful choice of species for each site, good planting practices, and adequate vegetation control. For example, in localities where the white pine blister rust is known to be serious, avoid planting white pine on sites where currants and gooseberries grow unless these plants can be permanently eradicated. Planting redcedar within a mile of apple or pear orchards may result in damage to both the redcedar and the orchards. Improper planting, resulting in a mass of tangled roots, may increase the possibility of serious root rots (60); and planting red pine in climates different than the climate of its natural range often results in severe attacks by the European pine shoot moth (Rhyacionia buoliana Schiff.).

It is beyond the scope of this bulletin to give a detailed account of all plantation insect pests and diseases. Only those that may seriously affect the success of species commonly planted can be listed (tables 17 and 18 in appendix), together with identifying symptoms, possible control measures, and references giving more detailed information. If serious epidemics occur, professional advice on control measures should be obtained.

Serious damage to young plantations of all species by white grubs (Phyllophaga spp.) may occur in some sections of the Central States. On those sites where high infestations do occur, however, some control measures are desirable. If sample excavations made in late spring or summer indicate a population of more than one white grub per cubic foot of soil, serious damage to planted seedlings are likely. To reduce mortality on these sites the roots of seedlings should be dipped in a 2-percent aldrin emulsion, just before planting. Attachments for spraying chemicals on the roots of seedlings and surrounding soil are obtainable for some planting machines. For spraying of this kind for white grubs a 1-percent emulsion of aldrin is recommended.

WHERE TO GET MORE HELP

Much additional information on tree planting is found in the references given in this bulletin (see Literature Cited, page 158). Technical assistance in planning tree-planting projects may be obtained from the local farm (or service) forester. The names and addresses of farm foresters can be obtained from ths State Division of Forestry (see list on page 65). In addition, the County Agricultural Agent, consulting forester, and the local Soil Conservation Service leader may supply the information desired or give advice on contacting the state extension forester, State Agricultural Experiment Station, or U.S. Forest Service Experiment Stations.

SPECIES SELECTION GUIDES

Species Selection Guides have been prepared for each state in the region to aid the landowner in choosing the right species for planting (tables 11 to 16). Although the landowner usually has some latitude in deciding what products to grow (see tables 4 and 5, pages 39, 40, and 41), the species selected to grow these products must be adapted to the local climate and site. The importance of choosing only those species adapted to the site cannot be overemphasized. The guides are prepared to aid in the on-the-ground recognition of those features of soil, topography, and vegetation that are important in choosing species for planting. Unless the landowner is familiar with these features on the land selected for planting, he should examine the site or have it examined by a qualified technician before choosing the species and deciding what methods of site preparation and planting to use.

The guides are intended primarily for plantings for erosion control and the growing of wood products. Although a number of the species included are also suitable for Christmas trees, the list of species for this purpose is by no means complete.

In selecting species for each site, careful consideration was given to recommendations from the woodland conservationists of the Soil Conservation Service and from foresters of the state divisions of forestry and agricultural experiment stations in the region (6) (7) (110). The forestry staff of Iowa State University was especially helpful in preparing the Guide for that state (64).

HOW TO USE THE SPECIES SELECTION GUIDES

The information given in the Species Selection Guides is classified under three major headings: Planting Site Class, Soil Series, and Species to Plant. Under the first, Planting Site Class, in the left-hand column, are listed the distinctive site features that can be recognized by an appraisal of surface characteristics and soil properties. Each planting site class is assigned an identifying number. In some states the U.S. Soil Conservation Service has classified soils for forest planting into groups. Each group consists of soil series that are somewhat similar in such soil properties as texture, rooting depth, drainage, parent material, and productivity. In states where this information was available, the planting site classes are based primarily on these soil groups.

However, in order that other important factors (chiefly, depth of topsoil, slope position, aspect, and erosion) that vary within soil groups and soil series may be considered, a further breakdown of planting site classes into subclasses is necessary. Subclasses are designated as "a", "b", "c", and so forth. For example, Planting Site Class No. 2 for Ohio is subdivided into 2a (more than 7 inches topsoil), and 2b (topsoil 3-7 inches thick).

Most planting site classes include two or more soil groups and many soil series. Even though there may be differences in characteristics among the soil groups and series in one planting site class, the same species in the same order of priority are suitable for planting on any of them. White pine, for example, may grow faster on some soils than on other soils in the same class, but it is nevertheless the best species for planting on all soils in the class.

The Soil Series associated with each planting site class are listed in the middle column of the Species Selection Guides. For readers familiar with this system of soil classification, or if up-to-date soil survey maps are available, this list of soil series will aid in identifying planting site classes.

Species to Plant appear in the double column on the right. Species are listed for each site in order of preference; separate lists are given for open, nonstocked land and for cutover or poorly stocked land. "Difficult planting chance" means that although the site is plantable, tree planting will be difficult and costly because of the density of vegetation and the need for two or more release cuttings.

Seriously eroded and gullied land presents special problems and is suitable for only a few species in each state. Such land is, therefore, not correlated with any specific soil group or soil series.

Figure 34.--Few species are adapted to severely eroded land. Compare growth and survival of 7-year old trees in foreground, where all topsoil has been eroded, with background where 1 to 3 inches of topsoil remain, for white (a), pitch (b), loblolly (c), and Virginia pines (d).

Table 11.--Species selection guide for forest planting in Illinois

Planting site class	Soil series (35) (135) (148) (164)	Species to plant (in order of preference)	
		On open non-stocked land	On cutover or poorly stocked land
1. Severely eroded land; sheet erosion so severe that there is less than 3" of top soil. May or may not be gullied.	All severely eroded soils		
a. North of U.S. Route 40.		jack pine redcedar red pine	red pine redcedar jack pine
b. South of U.S. Route 40.		shortleaf pine Virginia pine redcedar	shortleaf pine redcedar Virginia pine
NORTHERN ILLINOIS[1] UPLANDS			
2. Well drained, medium-textured soils, with permeable subsoils. Level to steeply sloping land.	Seaton, Fayette, Downs, Dodgeville (d.ph.), Ellison, Fox, Onarga, Alvin, Dubuque (d.ph.) Clary, Baylis, Camden, Palestine	white pine Norway spruce red pine European larch black walnut black locust	Difficult planting Chance:[2] white pine black walnut white ash Norway spruce N. red oak
a. North and east aspects.			
b. South and west aspects.		red pine Norway spruce European larch redcedar black locust	white pine Norway spruce N. red oak black walnut white ash redcedar

See footnotes on last page.

Table 11.--Species selection guide for forest planting in Illinois (con.)

3. Moderately well drained, medium-textured soils; subsoils tight but moderately permeable. Slightly more droughty than soils in Planting Site Class 2. Rolling to steep uplands.	Schapville (d.ph.), Morley, Blount, Beecher, Starks, Clinton, O'Fallon, Hickory	red pine jack pine white pine European larch Norway spruce redcedar	Difficult Planting Chance:[2] white pine N. red oak Norway spruce white ash redcedar
a. North and east aspects.			
b. South and west aspects.		red pine jack pine redcedar	red pine redcedar Norway spruce
4. Moderate to poorly drained, medium-textured soils; fine-textured silty or clayey subsoils. Nearly level to steeply sloping land.	Schapville (sh.ph.), Eylar, Chatsworth, Berwick, Atlas, Fishhook, Tomalco, Colp, Stoy	sycamore cottonwood white ash white pine redcedar	white ash green ash redcedar white pine sycamore
5. Sandy soils, or loamy sands, excessively droughty except where high water tables occur. May have sandstone bedrock 20 to 30 inches below surface. Water table deeper than 4 feet in midsummer.	Sumner, Hagner, Bloomfield, Unity, Plainfield, Perks	white pine red pine jack pine redcedar	white pine red pine redcedar
a. North and east aspects			
b. South and west aspects		jack pine redcedar	redcedar

See footnotes on last page.

Table 11.--Species selection guide for Illinois (con.)

6. Well drained, medium-textured soils that occur over calcareous sands and gravels. These are characteristically droughty soils in late summer and early fall.	Lorenzo, Rodman, Chute, Hennepin, Bold	red pine jack pine white pine	white pine red pine jack pine
7. Shallow soils over bedrock less than 15 inches from surface. Bedrock usually limestone. (In driftless area of northwestern Illinois)	Dodgeville, Romeo, Sogn, Rough Stoney Land	redcedar jackpine	redcedar
	NORTHERN ILLINOIS[1] LOWLANDS		
8. Sands and loamy sands; a. Water table 18" to 4' from surface in midsummer.	Homer, Watseka, Maumee, Kilbourne, Hoopston, Cowling, Milroy	white pine red pine jack pine Norway spruce European larch	Difficult Planting Chance:[2] white pine Norway spruce red pine
b. Water table less than 18" from surface in midsummer.		cottonwood sycamore silver maple	do not plant
9. Heavy clay bottomlands, normally dark colored. Claypans. Difficult planting sites.	Denny, Brooklyn, Ward	sycamore cottonwood redcedar	do not plant

See footnotes on last page.

Table 11.--Species selection guide for Illinois (con.)

10.	Poorly drained mineral or organic soils in depressions. Natural regeneration usually better than planting.	Houghton, Lena	do not plant	do not plant
		SOUTHERN ILLINOIS CLAYPAN AREA[3]		
11.	Medium to fine-textured, steep to gently rolling eroded soils, moderately permeable.	Richview, Ava, Grantsburg, Hosmer, Sciotoville, Stolle, Bogeta	shortleaf pine loblolly pine red pine redcedar	shortleaf pine white pine loblolly pine red pine redcedar
12.	Fine-textured, imperfect to somewhat poorly drained soils; silty or clayey mottled subsoils. Nearly level to rolling land.	Weinbach, Robbs, Stoy, Colp, Bluford, Hurst	redcedar sycamore cottonwood Virginia pine	Difficult Planting Chance:[2] redcedar sycamore pin oak
13.	Claypans; very slowly permeable mottled subsoils; level.	Cisne, Wynoose, Ward, Cowden, Weir, Henry, Ginat	sycamore sweetgum cottonwood redcedar	do not plant

See footnotes on last page.

Table 11.--Species selection guide for Illinois (con.)

	SOUTHERN ILLINOIS HILLY UPLANDS[4]			
14.	Well drained medium-textured soils that occur on gently rolling to steep land; moderately permeable with little or no restriction to root development. Includes a few soils with fragipans that somewhat restrict root penetration.	Alford, Stookey, Hickory, Zanesville, Wartrace	shortleaf pine loblolly pine white pine black walnut black locust	Difficult Planting Chance:[2] North and east aspects: yellow-poplar N. red oak black walnut white ash white pine loblolly pine South and west aspects: white pine loblolly pine N. red oak shortleaf pine
	a. Topsoil at least 7" thick, generally but not always on northerly and easterly slopes, coves, and lower slopes.			
	b. Topsoil 3 to 7" thick, generally on upper south and west slopes and dry, exposed ridges.		shortleaf pine loblolly pine white pine redcedar	white pine loblolly pine shortleaf pine redcedar
15.	Shallow soils over chert or solid bedrock	Rough Stoney Land, Bodine, Muskingum, Wellston,	shortleaf pine redcedar loblolly pine	redcedar shortleaf pine loblolly pine

See footnotes on last page.

Table 11.--Species selection guide for Illinois (con.)

SOUTHERN ILLINOIS TERRACES AND ALLUVIAL BOTTOMLANDS[5]			
16. Deep sandy to medium-textured silty soils, periodically flooded.	Alluvial Bottomlands: Haymond, Wakeland, Sharon, Belknap, Kemper, Birds, Bonnie, Beaucoup Terraces: Wheeling, Camden, Palestine, Onarga, Alvin, Sumner, Hagner, Bloomfield, Perks, Uniontown, Drury	cottonwood sycamore sweetgum yellow-poplar black walnut white ash silver maple	Difficult Planting Chance:[2] sweetgum yellow-poplar black walnut white ash bur oak
a. Well drained; no standing water on surface or to depths of 18" for periods longer than 10 days during growing season.			
b. Frequently ponded; water standing on surface or to depth of 18" for periods longer than 10 consecutive days during growing season		cottonwood sycamore sweetgum silver maple baldcypress	Difficult Planting Chance:[2] sweetgum white ash sycamore cottonwood pin oak

[1]Northern Illinois includes entire state north of the Claypan area, roughly all land north of a line from Paris in Edgar County to Alton in Jersey County.

[2]Difficult planting chance - this means that although the site is plantable, tree planting will be difficult and costly because of the density of vegetation; after initial clearing, one or more release cuttings, one to five years after planting, may be needed.

[3]Southern Illinois Claypan Area includes the flats and rolling uplands in southern Illinois that are not alluvial nor hilly uplands.

[4]Hilly uplands of southern Illinois - rough, hilly land, extending from Hardin to Union Counties in the southern part of the region and from Union to Jersey Counties in the western part of southern Illinois.

[5]All terraces along streams in southern Illinois; most extensive locations are the terraces along the Mississippi, Ohio and Wabash Rivers.

Table 12.--Species selection guide for Indiana

Planting site class	Soil series (117)	Species to plant (in order of preference)	
		On open non-stocked land	On cutover or poorly stocked land
1. Severely eroded land; sheet erosion so severe that there is less than 3" topsoil; may or may not be gullied. a. North of U.S. Route 40.	All severely eroded soils	jack pine red pine	red pine
b. South of U.S. Route 40.		Virginia pine shortleaf pine loblolly pine	Virginia pine shortleaf pine
GLACIAL SOILS (including old lake beds, outwash plains, and hilly uplands)			
2. Well drained and moderately well drained sandy soils. The surface soils are usually slightly to medium acid. These soils are underlain by sand, gravel or stones and are highly permeable. Level to gently sloping land.	Berrien, Boyer, Casco, Coloma, Fox, Nekoosa, Oakville, Oshtemo, Ottawa, Ottokee, Perrin, Plainfield, Rodman, Seward, Spinks, Teegarden, Tyner	red pine jack pine white pine	Difficult Planting Chance: [1] white pine

See footnotes on last page.

Table 12.--Species selection guide for Indiana (con.)

3.	Well drained or moderately well drained medium-textured soils with a root zone generally permeable. Subsoils usually clayey, but somewhat permeable. Uplands and plains.	Belmore, Bremen, Cana, Celina, Cincinnati, Edenton, Gibson, Grayford, Hanna, Hillsdale, Jennings, Kalamazoo, Longlois, Miami, Negley, Parke, Pike, Rossmoyne, Rush, Russell, Sisson, Sunfield, Tracy, Tuscola, Wynn, Xenia	white pine red pine	Difficult Planting Chance: [1] white pine yellow-poplar black walnut N. red oak
	a. More than 7" of topsoil; erosion slight to moderate.			
	b. Topsoil 3-7" thick; erosion moderate to severe.		white pine jack pine red pine	white pine N. red oak red pine
5.	Well drained upland and lacustrine soils with slowly to very slowly permeable clay subsoils. Gently rolling to steep land.	Aboite, Galena, Lucas, Markland, Morley, St. Clair, Uniontown,	shortleaf pine[2] loblolly pine[3] white pine	white pine shortleaf pine[2] loblolly pine[3]
5.	Imperfectly to poorly drained soils with silt pans or clay pans on gently sloping to slightly undulating land. Subsoils usually saturated in spring of the year.	Avonburg, Clermont, Loy, Mullins, Vigo, Weir	sweetgum sycamore cottonwood pin oak	sweetgum pin oak sycamore

See footnotes on last page.

Table 12.--Species selection guide for Indiana (con.)

RESIDUAL UPLAND SOILS (chiefly of sandstone, shale, and limestone origin)			
6. Well and moderately well drained medium-textured soils that occur on gently rolling to steep land; moderately permeable with little or no restriction to root development. Derived principally from sandstone and shale. Includes a few soils with fragipans that somewhat restrict root penetration.	Muskingum, Tilsit, Wellston, Zanesville, Christian (derived partly from loessial material)	white pine loblolly pine[3] shortleaf pine black walnut black locust yellow-poplar	North and east aspects: Difficult Planting Chance: [1] yellow-poplar N. red oak black walnut white ash white pine loblolly pine[3] South and west aspects: white pine loblolly pine[3] N. red oak shortleaf pine
a. Topsoil at least 7" thick, generally but not always on northerly and easterly slopes, coves, and lower slopes.			
b. Topsoil 3 to 7" thick, generally on upper south and west slopes and dry, exposed ridges.		white pine shortleaf pine loblolly pine[3]	white pine shortleaf pine
7. Well drained to excessively well drained coarse and medium-textured soils on rolling to steep land. Underlain immediately by shale or coarse to medium-textured subsoils.	Colyer	shortleaf pine loblolly pine[3]	shortleaf pine loblolly pine[3]

See footnotes on last page.

Table 12.--Species selection guide for Indiana (con.)

8.	Poorly to imperfectly drained soils with silt pan or clay pans that restrict root penetration and water movement. Nearly level uplands usually saturated in spring.	Johnsburg	sweetgum sycamore shortleaf pine loblolly pine[3]	sweetgum N. red oak white ash shortleaf pine loblolly pine[3]
9.	Shallow rocky limestone soils, with fine-textured subsoil limestone bedrock 6 to 20" below surface. Strongly sloping to steep. a. Topsoil more than 7"	Fairmount, Corydon, Milton, (shallow phase) Orleans, Rugby	white pine shortleaf pine	white pine shortleaf pine
	b. Topsoil 3 to 7"		shortleaf pine	white pine shortleaf pine
10.	Well drained, deep limestone soils, either rocky or shallow limestone. Limestone bedrock usually deeper than 20". Gentle to strongly sloping uplands. a. Topsoil more than 7"	Crider, Bewleyville, Frederick, Hagertown, Pembroke, Russellville	white pine shortleaf pine loblolly pine[3] black walnut black locust white ash red oak	North and east aspects: Difficult Planting Chance[1]: black walnut N. red oak white ash white pine South and west aspects: white pine loblolly pine[3] black walnut N. red oak white ash
	b. Topsoil 3-7"		shortleaf pine loblolly pine[3] white pine	white pine

See footnotes on last page.

	WINDBLOWN UPLAND SOILS (parts of southwestern Indiana)			
11.	Well drained, deep soils developed in relatively thick deposits of windblown loessial materials, on gently sloping to steep topography.	Bloomfield, Hosmer, Manlove, Oaktown, Princeton, Birbeck	shortleaf pine white pine	white pine shortleaf pine
	BOTTOMLAND SOILS (first bottoms, terraces, and depressions, derived from varied materials)			
12.	Well to moderately well drained medium-textured soils on first bottoms and terraces along streams and rivers	Adler, Eel, Boehne, Elkinsville, Genesee, Griffin, Huntington, Haymond, Lindside, Martinsville, Rahm, Morganfield, Philo, Pope, Pekin, Ockley, Sciotoville, Uniontown, Wheeling, Wilbur, Woodmere	cottonwood sweetgum baldcypress[4] white pine black walnut white ash	Difficult Planting Chance: [1] white ash sycamore black walnut sweetgum white pine
13.	Imperfectly to poorly drained soils on level to slightly undulating areas. Subsoils usually saturated with water in spring of year.	Developed from limestone: Guthrie, Lawrence Developed from glacial till: Washtenaw, Bethel, Delmar, Inwood, Blount, Nappanee, Crosby, Brookston, Kokomo, Keysport, Developed from outwash, terrace, or lacustrine (lakebed) soils: Whitaker, Sleeth, Westland, Abington, Kibbee, Colwood, Robinson, Wahalasville, Needham, Bartle, Peoga, Vincennes, Weinbach, Ginat, Chilo, Henshaw, Patton, Dubois, Developed from loess: Reesville, Ward, Ragsdale, Iva, Ayrshire Developed from loess, sandstone and shale: Mullins	sweetgum sycamore cottonwood silver maple baldcypress[4]	Difficult Planting Chance: [1] sweetgum silver maple

Table 12.--Species selection guide for Indiana (con.)

14.	Poorly drained organic soils	Carlisle, Tawas, Linwood, Willette, Rifle, Peat, Adrian, Palms, Houghton, Edwards, Warners, Kerston, Wallkill	do not plant	do not plant

[1]Productive sites, with dense tree and ground cover; control of vegetation will be difficult; depending on choice of species, one or more releases will be needed.

[2]Do not plant shortleaf pine north of U.S. Route 40.

[3]Do not plant loblolly pine north of U.S. Route 50.

[4]Plant baldcypress only on sites south of U.S. Route 40.

Table 13.--Species selection guide for Iowa

Planting site class	Common soil series (159)	Species to plant (In order of preference)
EASTERN IOWA (from U.S. Route 69 east to the Mississippi River)		
1. Sandy soils, or finer-textured soils over bedrock less than 15" from surface.	Sogn, Thurman, Dickinson, Chelsea, Lamont, steep stony land	North and east aspects, coves and second bottoms: white pine, red pine, jack pine, redcedar South and west aspects, ridge tops: jack pine, red pine, redcedar
2. Deep, well-drained medium-textured soils; generally permeable, but includes some that are moderately impermeable at depths greater than 18".	Fayette, Dubuque, Quandahl, Tawa, Carrington, Coggon, Chanburg, Givin, Berwich, Mahacka, Otten, Taintor, mixed alluvium	North and east aspects, coves and second bottoms: white pine, red pine, European larch, Norway spruce[1] white spruce[1], black walnut, cottonwood, green ash South and west aspects: white pine, red pine, jack pine, European larch Alluvial, bottomland soils: cottonwood, sycamore, silver maple, green ash, hackberry, black walnut
3. Moderate to poorly drained, shallow, clay loams, silty clays, and clays; "tight" slowly permeable, subsoils.	Zwingle, Schapville, Traer, Marion, Weller, Lindley, Shelby, Gosport, Keomah, Bucknell, Pershing, Belinda, Bauer, Grundy, Haig, Sperry, Seymour, Edina, Clarindon, Lagonda, mixed alluvium	North and east aspects, coves and second bottoms: green ash, redcedar, white pine, hackberry, cottonwood, silver maple, Norway spruce[1], South and west aspects: redcedar, jack pine, cottonwood, green ash, hackberry Bottomlands: cottonwood, green ash, sycamore, silver maple

See footnotes on last page.

Table 13.--Species selection guide for Iowa (con.)

WESTERN IOWA (from U.S. Route 69 to western boundary of state)			
4.	Droughty soils; well-drained sandy, or medium-textured soils with low moisture-holding capacity.	Hamburg, Ida, Arion	redcedar, Rocky Mountain juniper
5.	Deep, well-drained soils; generally permeable but includes some soils that are moderately impermeable at depths greater than 18".	Monoma, Marshall, Castana, Napier, Steinauer, Minden, Hormick-first bottom, Sharpsburg, Winterset, Ladoga, Nodaway, mixed alluvium	North and east aspects, coves and second bottoms: redcedar, European larch, white pine[2], black walnut, cottonwood, white spruce[2], South and west aspects: redcedar, Rocky Mountain juniper, jack pine, European larch Bottomlands: cottonwood, silver maple, hackberry, black walnut, sycamore
6.	Moderate to poorly drained, shallow clay loams, silty clays, and clays; "tight", slowly permeable subsoils.	Clarinda, Luton-first bottoms, Shelby, Lagonda, Gara, Malvern, Wabash, and mixed alluvium	North and east aspects, coves and second bottoms: redcedar, sycamore, cottonwood, green ash, silver maple, hackberry South and west aspects: redcedar, bur oak, sycamore, cottonwood, hackberry Bottomlands: sycamore, cottonwood, silver maple, green ash

[1]Plant in northeast Iowa only, north of U.S. Route 6.

[2]Do not plant on sites with calcareous topsoils.

Table 14.--Species selection guide for Kentucky

Planting site class	Soil series (73)	Species to plant (In order of preference)	
		On open non-stocked land	On cutover or poorly stocked land
1. Severely eroded land; sheet erosion so severe that there is less than 3" of topsoil; may or may not be severely gullied. a. Subsoil coarse to moderately fine-textured.	All severely eroded soils	loblolly pine shortleaf pine Virginia pine	loblolly pine shortleaf pine Virginia pine
b. Subsoil fine-textured with compact clay, sometimes with limestone slabs or marl outcrops.		redcedar	redcedar
2. Well-drained to moderately well-drained, medium-textured, moderately deep to shallow soils on gently rolling to steep land; derived from sandstone, shale, and/or silt stones. a. Coarse to medium-textured subsoils, generally on north and east steep slopes.	Hector (Cool slopes)[1] Muskingum (Cool slopes)	white pine loblolly pine shortleaf pine black walnut black locust	Difficult Planting Chance: [2] yellow-poplar N. red oak black walnut white ash white pine loblolly pine
b. Soils moderately deep to fragipans, or shallow to sandstone or shale, on level to sloping land. (Muskingum and Hector on sloping to steep)	Bedford, Captina, Cincinnati, Coolville, Dickson, Freeland, Grenada, Hector, (lower hot slopes)[1], Kenton, Landisburg, Lax, Leadvale, Loudon, Mercer, Mobely, Monongahela, Muskingum (lower hot slopes)[1], Nicholson, Pearman, Providence, Richland, Rossmoyne, Sango, Sciotoville, Tilsit, Whitwell, Zaleski, Zanesville	loblolly pine shortleaf pine white pine	white pine loblolly pine shortleaf pine

3.	Deep, well-drained, gentle to strongly sloping upland and terrace soils; with rapid to moderately permeable, medium to moderately fine-textured subsoils; underlain by limestones, sandstones, and/or shales. a. Topsoil more than 7" thick.	Allegheny, Apison, Allen, Ashburn, Ashton, Armour, Beleyville, Baxter, Brandon, Braxton, Christian, Cookeville, Caylor, Capshaw, Crossville, Crider, Cruze, Cumberland, Decatur, Dexter, Ells, Etowah, Frankstown, Faceville, Fleming, Hagerstown, Hayter, Hermitage, Holston, Humphreys, Jefferson, Loradale, Loring, Lexington, Linker Kintonia, Malt, Manse, Memphis, Maury, Mountview, Nolichucky, Pembroke, Pace, Negley, Pickwick, Rennox, Ruston, Russelville, Sequatchie, Shelbyville, Waynesboro, Wheeling, Wolftever, Trappist, Wellston	white pine loblolly pine shortleaf pine black walnut black locust	Difficult Planting Chance: [2] white pine loblolly pine N. red oak black walnut yellow-poplar white ash
	b. Topsoil 3 to 7" thick.		shortleaf pine loblolly pine white pine	white pine loblolly pine shortleaf pine
4.	Well-drained to excessively well-drained coarse and medium-textured soils on rolling to steep land: underlain immediately by shale or coarse-textured parent material of variable origin.	Bodine, Beulah, Bruno, Colyer, Culleoka, Guin, Hartsells, Iola, Lakin, Muskingum (upper hot slope)[1], Rockcastle, Westmoreland	shortleaf pine loblolly pine	loblolly pine shortleaf pine
5.	Well to moderately well-drained upland soils with thin clay subsoils, or rocky and shallow to thin-bedded limestones or calcareous shale with clay subsoils; usually eroded.	Ashwood, Eden, Edenton, Colbert, Talbott, Caneyville, Corydon, Fairmount, Otway, Tumbez, Westmoreland (very rocky phase), Auburn (very rocky phase), Hagerstown, (shallow and rocky phases), Maury (shallow phase), Pembroke (shallow and rocky phases), Salvisa (very rocky phase)	redcedar	redcedar

See footnotes at end.

Table 14.--Species selection guide for Kentucky (con.)

6.	Well-drained upland and terrace soils with medium to slow internal drainage and clay subsoils of limestone and/or shale origin; gently to strongly sloping. a. Topsoil more than 7" thick.	Beasley, Bigbone, Brashear, Donerail, Enders, Hampshire, Heitt, Jessup, Licking, Lowell, Maddox, Markland, Muse, Needmore, Rarden, Salvisa silt loam, Swaim, Uniontown, Upshur, Weon, Woolper	white pine shortleaf pine loblolly pine	Difficult Planting Chance: [2] white pine N. red oak
	b. Topsoil 3 to 7" thick.		redcedar	redcedar
7.	Moderately well to well-drained, medium to coarse-textured bottom soils of variable origin. Fertile, highly productive land.	Adler, Barbourville, Collins, Commerce, Egam, Ennis, Huntington, Hymon, Lindside, Lobelville, Morganfield, Philo, Pope, Robinsonville, Staser, Shannon, Vicksburg	cottonwood yellow-poplar black walnut black locust sweetgum white pine loblolly pine baldcypress	Difficult Planting Chance: [2] Do not plant unless cleared and cultivated. cottonwood yellow-poplar black walnut black locust sweetgum white pine loblolly pine baldcypress
8.	Poorly to somewhat poorly drained bottom, terrace, and upland soils a. Slopes less than 2 percent.	Atkins, Avonburg, Blago, Burgin, Calhoun, Calloway, Carroll, Caseyville, Clermont, Cotaco, Dekoven, Dunning, Elkins, Falaya, Fawcett, Ginat, Guthrie, Henry, Henshaw, Ina, Inglefield, Johnsburg, Lawrence, Lee, Lickdale, McGary, Melvin, Mhoon, Mullins, Newark, Olivier, Purdy, Robertsville, Roellen, Sees, Stendal, Taft, Tupelo, Tyler, Waverly, Weinbach, Zipp	baldcypress sweetgum sycamore pin oak cottonwood	Difficult Planting Chance: [2] sweetgum pin oak sycamore baldcypress
	b. Slopes 2 percent or more.		baldcypress loblolly pine shortleaf pine sycamore sweetgum pin oak	Difficult Planting Chance: [2] sweetgum pin oak sycamore baldcypress loblolly pine

Table 14.--Species selection guide for Kentucky (con.)

9. Very sandy, alluvial soils along streams and rivers.	Clack, Crevasse, sandy alluvial land	cottonwood sycamore sweetgum baldcypress	Difficult Planting Chance: [2] sweetgum sycamore cottonwood baldcypress

[1] "Hot slopes" are generally on south and west aspects, between Azimuth readings of 125 to 340 degrees; "cool slopes" are generally north and east aspects between Azimuth readings of 34 and 125 degrees.

[2] Productive sites with dense forest and ground cover; control of vegetation will be expensive. After initial clearing two or more release cuttings may be needed.

Table 15.--Species selection guide for Missouri

NORTHERN AND WESTERN MISSOURI (north of Missouri River and west of the Ozarks)

	Planting site class	Common soil series[1] (70) (71) (95) (149)	Species to plant (in order of preference)
1.	Well-drained sandy soil, or medium-textured soils with low water-holding capacity; some soils shallow to sandstone bedrock at 20 to 30". (Includes "river hills" and bluffs)	Sarpy sandy loam (60-64), Cass sandy loam (52), Boone (26-27), Knox-Menfro (18), Shallow Huntington (92-93), Marshall-Pettis (14), Nodaway-Sharon (66)	Uplands: redcedar, ponderosa pine[2] Austrian pine Bottomlands: cottonwood, silver maple, hackberry
2.	Deep, moderately well to somewhat poorly drained medium textured soils; includes some soils with 40" or more of silty surface soils and silty clay to clay subsoils.	Grundy (11), Shelby (16), Summit (11), Tama(14), Union (20), Winfield (20), Lindley (21)	North and east aspects: black walnut, green ash, black locust, cottonwood South and west aspects: jack pine, redcedar Bottomlands: cottonwood, sycamore, green ash, black walnut
3.	Poorly drained fine-textured soils with "tight" claypan subsoils.	Edina (28), Marion (10), Mexico-Parsons (24), Osage clay-Wabash clay (58), Putnam-Oswego (15), Seymour (29), Weldon (25)	Uplands: redcedar, sycamore, cottonwood, green ash, hackberry, silver maple Bottomlands: sycamore, cottonwood, green ash, hackberry

See footnotes on last page.

Table 15.--Species selection guide for Missouri (con.)

Ozark Region				
	Planting site class	Soil series	Species to plant (in order of preference)	
			On open non-stocked land	On cutover or poorly stocked land
4.	Severely eroded land; less than 3" of topsoil; gullied.	All severely eroded soils	eastern redcedar shortleaf pine loblolly pine[3]	eastern redcedar shortleaf pine loblolly pine[3]
5.	Well-drained, medium-textured soils; permeable subsoils for 40" or more. On areas bordering prairie some of these soils may have rock, sand or gravel at 24 to 36" depths, and somewhat droughty. Level to steeply sloping land, uplands and bottomlands. a. North and east aspects	Baxter (2), Craig (6), Loring-Memphis (19), Hagerstown (1)	shortleaf pine loblolly pine[3] eastern redcedar black locust black walnut	black walnut eastern redcedar green ash
	b. South and west aspects		shortleaf pine loblolly pine[3] eastern redcedar	shortleaf pine loblolly pine[3] eastern redcedar
	c. Bottomland	Huntington-Robinsonville (66)	loblolly pine[3] black walnut black locust	black walnut loblolly pine[3]
6.	Well-drained, stony or cherty-silty surface soils; permeable subsoil with rock, sand or gravel. Droughty soils on rolling to steep slopes.	Baxter cherty (3) or stony (4), Bodine cherty (5) or stony (4), Clarksville cherty (5) or stony (4), Elden (7), Gosport (17-31), Snead stony (13), Sogn stony (13)	shortleaf pine loblolly pine[3] eastern redcedar	shortleaf pine eastern redcedar loblolly pine[3]

See footnotes on last page.

Table 15.--Species selection guide for Missouri (con.)

7.	Moderate to poorly drained medium-textured surface soils, and 40" or more of fine-textured subsoils (silty clay to clay). Some of the soils near prairie land may have very heavy (claypan) subsoils. Level to steeply sloping land. a. Uplands	Grenada (20), Guthrie (10), Lebanon (9), Union (20) Nixa-Dixon (8)	loblolly pine[3] eastern redcedar shortleaf pine	eastern redcedar shortleaf pine loblolly pine[3] green ash
	b. Lowlands	Robertsville-Calhoun (10), Waverly (76)	loblolly pine[3] sycamore cottonwood green ash	do not plant unless cleared: sycamore cottonwood green ash
8.	Sandy soils, excessively drained and droughty. Upland soils have sandstone bedrock at 20 to 30". Uplands and bottomlands (stream gravel). a. Uplands	Hanceville (26), Tilsit (23), Collinsville (27)	shortleaf pine loblolly pine[3]	shortleaf pine loblolly pine[3]
	b. Lowlands	Stream gravel (96), Bottomlands: shallow to sandy or gravelly (91-94)	cottonwood sycamore loblolly pine[3]	do not plant unless cleared: cottonwood sycamore

See footnotes on last page.

Table 15.--Species selection guide for Missouri (con.)

SOUTHEASTERN LOWLANDS (the "Bootheel," and adjoining counties)			
9. Poorly drained, silt to clay surface soils and clay subsoils; includes the "gumbo" bottomlands; level to gently rolling land.	Alligator (79), Olivier (25), Robertsville (10), Sharkey (78), Waverly (76), Imperfectly to poorly drained bottomland soils with silty clay subsurfaces (67-54)	sycamore sweetgum cottonwood silver maple	do not plant
10. Sandy to medium-textured silty soils, deep, highly permeable. a. Well-drained; no standing water on surface or to depths of 18" for periods longer than 10 consecutive days during growing season.	Beulah (64), Clack (60), Sarpy (64), Deep, well drained bottomland soils (66)	cottonwood sycamore sweetgum yellow-poplar black walnut white ash silver maple	Difficult Planting Chance[4] sweetgum yellow-poplar black walnut white ash
b. Frequently ponded; water standing on surface or to depth of 18" for periods longer than 10 consecutive days during growing season.		cottonwood sycamore sweetgum silver maple baldcypress	Difficult Planting Chance[4] sweetgum white ash sycamore cottonwood

[1]The list of soil series in each planting site class is not complete; the number in parenthesis following a soil series refers to the basic soil series symbol occurring on soil surveys currently being made in Missouri by the Soil Conservation Service.

[2]Ponderosa pine planting stock from seed sources on the eastern slopes of the Rocky Mountains is advisable.

[3]Loblolly pine recommended only in counties adjoining Arkansas.

[4]Dense tree and crown cover will make site preparation difficult and expensive. Two or three cultivations during first growing season may be needed; subsequent release cuttings may also be needed.

Table 16.--Species selection guide for Ohio

RESIDUAL SOILS OF SOUTHERN AND SOUTHEASTERN OHIO

Planting site class	Soil series (104) (107) (108)	Species to plant (in order of preference)	
		On open non-stocked land	On cutover or poorly stocked land
1. Severely eroded land; sheet erosion so severe that there is less than 3" of topsoil. May or may not be gullied.	All severely eroded soils	Virginia pine shortleaf pine[1] loblolly pine[2] white pine	loblolly pine[2] Virginia pine shortleaf pine[1] white pine
2. Well drained medium-textured soils that occur on gently rolling to steep land; moderately permeable with little or no restriction to root development. a. Topsoil at least 7" thick, generally but not always on northerly and easterly slopes, coves, and lower slopes.	Derived chiefly from sandstone and shale: Wellston, Zanesville, Tilsit, Alford, Frankstown, Tuscarawas, Muskingum, Meigs, Stony Muskingum, Stony Meigs, Gilpin Derived partly from limestone or other calcareous material: Brooke, Belmont, Westmoreland,	white pine loblolly pine[2] shortleaf pine[1] red pine[3] yellow-poplar black walnut black locust European larch	Difficult Planting Chance: yellow-poplar N. red oak black walnut white ash white pine loblolly pine[2]
b. Topsoil 3 to 7" thick, generally on upper south and west slopes and dry, exposed ridges.		white pine shortleaf pine[1] loblolly pine[2] red pine[3]	white pine shortleaf pine[1] loblolly pine[2] red pine[3]
3. Well drained upland soils with moderate to slowly permeable clay subsoils. Rolling to steep land.	Rarden, Latham, Eifort, Trappist, Upshur, Coolville, Keene, Byington, Fawcett, Guernsey	shortleaf pine[1] loblolly pine[2] white pine red pine[3]	white pine shortleaf pine[1] loblolly pine[2] red pine[3]

See footnotes on last page.

Table 16.--Species selection guide for Ohio (con.)

4.	Shallow well drained to excessively well drained medium-textured soils on rolling to steep land. Underlain immediately by black shales.	Colyer	shortleaf pine[1] loblolly pine[2] Virginia pine white pine red pine[3]	shortleaf pine[1] loblolly pine[2] white pine
5.	Soils with clay subsoils of poor physical conditions, derived from calcareous shales. Moderately steep and usually severely eroded. a. Slight to moderate erosion; topsoil 3-7" thick.	Shallow Otway, Shallow Jacksonville, Shallow Bentonville	redcedar white pine Austrian pine Virginia pine	redcedar white pine Austrian pine Virginia pine
	b. Severely eroded; topsoil less than 3" thick; gullied.		redcedar Virginia pine	redcedar Virginia pine
6.	Shallow rocky limestone soils, with fine-textured subsoil. Limestone bedrock 6 to 20" below surface. Strongly sloping to steep. a. Topsoil more than 7" thick	Fairmount, Heitt, Otway, Corydon, Shallow Cedarville, Shallow or Stony Bratton	redcedar white pine shortleaf pine[1]	white pine redcedar shortleaf pine[1]
	b. Topsoil 3 to 7" thick		redcedar shortleaf pine[1] Virginia pine	shortleaf pine[1] Virginia pine redcedar

See footnotes on last page.

Table 16.--Species selection guide for Ohio (con.)

7.	Well and moderately drained deep limestone soils, derived from limestone. Limestone bedrock usually deeper than 20". Gentle to strongly sloping uplands.	Hagerstown, Maddox, Cedarville, Bratton, Bedford, Deep Jacksonville, Deep Bentonville	white pine shortleaf pine[1] loblolly pine[2] yellow-poplar black walnut black locust white ash Norway spruce	Difficult Planting Chance: white pine yellow-poplar black walnut N. red oak white ash Norway spruce
	a. Topsoil more than 7" thick.			
	b. Topsoil 3-7" thick.		shortleaf pine[1] Austrian pine loblolly pine[2] white pine	white pine loblolly pine[2] shortleaf pine[1] Austrian pine
	GLACIAL SANDSTONE AND SHALE SOILS OF NORTHEASTERN OHIO			
8.	Severely eroded land; sheet erosion so severe that there is less than 3" of topsoil. May or may not be gullied.	All severely eroded soils	Virginia pine jack pine red pine[3]	Virginia pine jack pine red pine[3]
9.	Shallow, droughty soils developed from thin glacial till over sandstone outcrops, or from acid sands and gravels.	Loudonville, Millwood, Massillon	Virginia pine red pine[3] jack pine white pine	white pine red pine[3]

See footnotes on last page.

Table 16.--Species selection guide for Ohio (con.)

10.	Well and moderately well-drained deep medium- to fine-textured soils with a medium to slowly permeable root zone. a. More than 7" of topsoil; erosion negligible.	Ellsworth, Wooster, Hanover, Fallsburg, Rittman, Canfield, Alexandria, Wayne	white pine Norway spruce European larch yellow-poplar sweetgum white ash black walnut	Difficult Planting Chance: white pine black walnut Norway spruce white ash N. red oak sweetgum sycamore
	b. Topsoil 3-7" thick; erosion moderate to severe.		white pine jack pine red pine[3]	white pine N. red oak red pine[3]
11.	Imperfect to very poorly drained, medium to fine textured deep soils on level or gently rolling till plains.	Wadsworth, Ravenna, Mahoning, Frenchtown, Marengo, Venango, Trumbull	sycamore sweetgum pin oak cottonwood silver maple	Difficult Planting Chance: sweetgum pin oak silver maple
	GLACIAL LIMESTONE SOILS OF WESTERN OHIO			
12.	Severely eroded land; sheet erosion so severe that there is less than 3" of topsoil. May or may not be seriously gullied. a. Subsoils coarse to medium-textured.	All severely eroded soils	Virginia pine shortleaf pine[1] loblolly pine[2]	Virginia pine shortleaf pine[1] loblolly pine[2] jack pine
	b. Subsoils fine-textured, with calcareous, compact clay.		redcedar Virginia pine	redcedar Virginia pine

See footnotes on last page.

Table 16.--Species selection guide for Ohio (con.)

13.	Shallow to moderately deep medium-textured soils underlain by gravel, calcareous glacial till, shale, or limestone.	Shallow Milton, Milton, Mill Creek, Ockley, Wea, Fox, Negley, Casco, Edenton, Romeo, Hennepin, Wynn, Rodman, Warsaw, Parke, Pike	white pine red pine Austrian pine shortleaf pine[1] loblolly pine[2] redcedar	white pine Austrian pine shortleaf pine[1] loblolly pine[2] redcedar
14.	Well- and moderately well-drained, deep medium- to fine-textured soils with medium to slowly permeable root zones. a. More than 7" of topsoil; erosion negligible.	Celina, Caesar, Ionia, Sardinia, Thackery, Tippecanoe, Corwin, Xenia, Dana, Cardington, Birkbeck, Grayford, Miami, Williamsburg, Kendallville, Russell, Wawaka, Sidell, Saybrook, Morley, Uniontown, Varna, Loudon, Rossmoyne, Jessup, Cincinnati, Jennings	white pine Austrian pine shortleaf pine[1] loblolly pine[2] sweetgum Norway spruce	Difficult Planting Chance: white pine yellow-poplar black walnut white ash sweetgum N. red oak Norway spruce
	b. Topsoil 3-7" thick; erosion moderate to severe.		Austrian pine shortleaf pine[1] loblolly pine[2] white pine	white pine N. red oak loblolly pine[2] shortleaf pine[1]
15.	Imperfect to very poorly drained, deep, medium- to fine-textured soils with medium to slow permeability; level to gently undulating till plains or in depressions.	Crosby, Massie, Sleeth, Crane, Weinbach, Odell, Fincastle, Bennington, Raub, Bonbas, Blount, Henshaw, Randolph, Blanchester, Elliot, Pitchin, Brookston, Westland, Montgomery, Abington, Kokomo, Millsdale, McGary, Cope, Pewamo, Chippewa, Ragsdale, Clermont, Bethel, Delmar, Condit, Wickliffe, Avonburg	sweetgum sycamore baldcypress cottonwood pin oak European larch	Difficult Planting Chance: sweetgum white ash silver maple

See footnotes on last page.

16.	Moderately well-drained, fine- to very fine-textured soils with a slow to very slowly permeable root zone. Sloping to moderately steep land.	Lucas, St. Clair, Broughton	white pine red pine[3] Austrian pine Norway spruce	white pine Norway spruce Austrian pine red pine[3]
	a. Topsoil more than 7" thick.			
	b. Topsoil less than 7" thick.		red pine[3] white pine Norway spruce	white pine Norway spruce Austrian pine red pine[3]
17.	Well-drained to poorly drained sandy soils. The surface soils are usually slightly to medium acid. These soils are highly permeable. Level to gently sloping land.	Ottokee, Oakville, Plainfield, Seward, Painesville, Haney, Tuscola,	jack pine red pine[3] white pine	white pine red pine[3]
	a. Water table deeper than 4' in summer.			
	b. Water table 18" to 4' in summer.	Rimer, Kibbie, Tedrow, Digby	white pine jack pine red pine[3]	white pine red pine[3]
	c. Water table less than 18" deep in summer.	Wauseon, Reynolds, Colwood, Milgrove, Granby, Maumee	cottonwood sycamore sweetgum silver maple	do not plant
18.	Poorly and imperfectly drained medium- to fine-textured soils on level areas. Subsoils usually saturated in spring.	Paulding, Nappanee, Toledo, Fulton, Hoytville, Latty, Caneadea, Canadice, Lorain, Fries, Olmstead, Wilmer, Haskins, Mermill, Roselms, Wickliffe	sycamore sweetgum silver maple cottonwood	Difficult Planting Chance: sweetgum silver maple sycamore cottonwood

See footnotes on last page.

Table 16.--Species selection guide for Ohio (con.)

19.	Poorly drained organic soils in depressional areas. (Natural regeneration usually better than planting.)	Muck, peat	do not plant	do not plant
		BOTTOMLAND (ALLUVIAL) SOILS THROUGHOUT OHIO		
20.	Well-drained medium-textured soils on first bottoms along streams and rivers.	Eel, Lobdell, Philo, Linside, Senecaville, Medway, Genessee, Chagrin, Pope, Huntington, Moshannon, Ross, Chili, Mentor, Holston, Monongahela, Wheeling, Colerain, Vincent, Glenford, (Vause)	cottonwood sweetgum baldcypress white pine black walnut white ash Norway spruce European larch	Difficult Planting Chance: white ash sycamore baldcypress black walnut sweetgum white pine
21.	Poorly to very poorly drained soils on level to slightly undulating areas. Subsoils usually saturated with water in spring of year.	Shoals, Orrville, Stendal, Newark, Defiance, Sloan, Papakating, Dunning, Elkins, Wabash, Tyler, Algiers, Wallkill, Melvin, Atkins	sweetgum sycamore baldcypress cottonwood silver maple	Difficult Planting Chance: sweetgum silver maple baldcypress

[1]Do not plant shortleaf pine north of U.S. Route 40.

[2]Do not plant loblolly pine north of U.S. Route 50, and use stock from Maryland, Delaware, or Virginia seed sources only.

[3]European Pine Shoot Moth is a very serious pest of red pine, particularly on sites located north of U.S. Route 40.

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APPENDIX

SUGGESTED PROCEDURES FOR MAKING PLANTING PLANS

The degree of detail required in making plans for planting depends to a large extent on the size of the area to be planted, the number of tracts to be planted, number of years required to complete the planting, the complexity of site conditions, and the existing knowledge of these site conditions. On small plantings no formal planting plans are necessary; on large operations, however, it is desirable to make site evaluations and to prepare "blueprints" for the planting. The following step-by-step procedures may be helpful in preparing these plans.

Land Ownership Status

Examine deeds to verify land ownership; look especially for easements granting rights to construct highways, powerlines, pipelines, or reservoirs, and for reservations in the title that provide rights for strip mining. Exclude these areas from the proposed planting site.

Appraisal of Planting Needs

1. Cover classes.--Survey each tract to determine the acreage of (1) land that does not need planting, (2) open, nonstocked land, (3) cutover or poorly stocked land, and (4) strip-mined land. On a large scale map (4 inches to the mile is suggested) mark out the boundaries of land in each of these classes.

2. Site evaluation.--Make a systematic survey of the land to be planted in sufficient detail to outline on the map areas with major differences in soil texture and structure, depth of topsoil, effective rooting depth, drainage, topography, parent material, and past use.

3. Planting site classes and subclasses.--Consult the Species Selection Guide for the state in which the planting site is located (pages 129 to 158). Select the planting site classes and subclasses that most closely coincide with the site evaluation data.

Access Roads and Fire Lanes

It is well to plan and lay out a road and fire-lane system in advance of planting. This will facilitate planting and future management of the plantation, especially if the land is to be furrowed, cultivated, or cleared. In general one truck trail 15 to 20 feet wide through each 40-acre block will suffice. Make use of old, established routes of travel as much as possible, unless they are so located that they constitute erosion hazards. If fire risks are high, fire lanes surrounding each 40 acres of plantation are desirable (page 122).

Site Preparation

If site preparation is necessary, designate location area, and kind on the map (see pages 45 to 69).

The Planting Job

In planning a large planting project it will be helpful to prepare a separate "Planting prescription" for each area differing from others in methods of site preparation, species to be used, spacing and planting arrangement. The prescription should include the methods of site preparation planned, number of trees by species needed, spacing, and whether planting will be pure or mixed. If mixed planting is planned the method of mixture should be prescribed. The seed source and stock-quality specifications should be included, as well as cost estimates and lists of equipment and materials needed.

Table 17.--Insect pests of forest plantations[1]

Tree species and pest[2]	Symptoms	Control measure		
		Insecticide	Reference	
			Author[3]	Page
ASH, green and white The ash borer *Podosesia syringae fraxini* (Lug.)	bore trunk at ground level	DDT spray on trunk	--	--
Oystershell scale *Lepidosaphes ulmi* (L.)	weakens tree, may kill	Dormant oil spray	English (43)	8
Fall webworm *Hyphantria cunea* (Drury)	webbing of branches, foliage	Lead arsenate	English (43)	9
CATALPA				
Catalpa sphinx *Ceratomia catalpae* (Bdv.)	defoliation	Lead arsenate or DDT spray	English (43)	14
COTTONWOOD				
Poplar borer *Saperda calcarata* (Say)	frass at base of tree	DDT application on trunk	English (43)	59
Poplar and willow borer *Sternochetus lapathi* (L.)	bore in branches and trunk	DDT application	English (43)	59
Cottonwood leaf beetle *Chrysomela scripta* F.	leaves skeletonized	Lead arsenate or DDT spray	English (43)	60

See footnotes on last page of table.

Table 17.--Insect pests of forest plantations (con.)

Tree species and pest	Symptoms	Control measure		
		Insecticide	Reference	
			Author	Page
HACKBERRY				
Hackberry nipple gall *Pachypsylla celtidis-mamma* (Flet.)	conspicuous growths on leaves	Lindane spray	English (43)	35
LARCH, European				
Spruce budworm *Choristoneura fumiferana* (Clem.)	defoliation	DDT	Craighead (34)	480 482
Larch sawfly *Pristiphora erichsonii* (Htg.)	defoliation	DDT	Craighead (34)	573 574
LOCUST, black				
Locust borer *Megacyllene robiniae* (Forst.)	bores into sapwood, heartwood	DDT spray	English (43)	40
MAPLE, silver				
Maple callus borer *Sylvora acerni* (Clem.)	frass around wounds	none recommended	Craighead (34)	462
Cottony maple scale *Pulvinaria innumerabilis* (Rathv.)	cottony mass on branches, twigs	Dormant spray winter, Malathion summer	English (43)	43
OAK, red, bur				
Kermes pubescens (Bogue)	distort--kill, shoots, leaves	Dormant oil spray	English (43)	50
Gall insects numerous species (cynipids)	abnormal swelling of twigs	Rarely serious enough to justify spraying	English (43)	50

Table 17.--Insect pests of forest plantations (con.)

Tree species and pest	Symptoms	Control measure		
		Insecticide	Reference	
			Author	Page
OSAGE-ORANGE				
Fruit tree leaf roller Archips argyrospila (Wlk.)	web leaves together	DDT spray	Craighead (34)	478
European fruit lecanium Lecanium corni (Bouché)	scale on twigs, branches	Dormant spray	Craighead (34)	145
PINE				
Sawflies Neodiprion spp.	defoliation	DDT	English (43) McDowell (82)	53 64
Bark beetles Ips spp., Dendroctonus spp.	engraving in cambium area	BHC	Craighead (34)	294 336
Weevils Hylobius spp, Pissodes spp.	gnawing of bark and cambium	BHC	Craighead (34)	281 287
PINE, loblolly, shortleaf				
Rhyacionia frustrana (Comst) Rhyacionia rigidana (Fern)	bud and twig mortality	DDT	English (43)	57
PINE, red				
European pine shoot moth Rhyacionia buoliana (Schiff)	bud mortality, brooming	DDT	English (43) McDowell (82)	57 59 60
PINE, Scotch				
Zimmerman pine moth Dioryctria zimmermani (Grote)	terminal, tree killing	DDT	English (43)	58

Table 17.--Insect pests of forest plantations (con.)

Tree species and pest	Symptoms	Control measure		
		Insecticide	Reference	
			Author	Page
PINE, white				
White pine weevil *Pissodes strobi* (Peck)	new growth on leader turns over and wilts, needles and bark turn brown, resin blobs on leader	DDT	Craighead (34)	281 287
REDCEDAR, Eastern				
Bagworm *Thyridopteryx ephemeraeformis* (Haw.)	defoliation	Malathion	English (43)	37
Aphid *Cinara sabine*	honeydew on branches	DDT	McDowell (82)	46
SPRUCE, Norway; white				
Spruce budworm *Choristoneura fumiferana* (Clem)	defoliation	DDT	Craighead (34)	480 482
Eastern spruce gall aphid *Chermes abietis* L.	pineapple-like galls on twigs	Lindane	English (43)	64
SWEETGUM				
Forest tent caterpillar *Malacosoma disstria* Hbn.	defoliation	Lead arsenate spray	Craighead (34)	418
SYCAMORE				
Sycamore lace bug *Corythucha ciliata* (Say)	leaves become pale and dry	Malathion spray	English (43)	65
Bagworm *Thyridopteryx ephemeraeformis* (Haw.)	feeds on leaves	Lead arsenate or malathion spray	English (43)	66

Table 17.--Insect pests of forest plantations (con.)

Tree species and pest	Symptoms	Control measure		
		Insecticide	Reference	
			Author	Page
WALNUT, black				
Walnut caterpillar *Datana integerrima* G. & R.	defoliation	Lead arsenate or DDT spray	English (43)	67
Black walnut curculio *Conotrachelus retentus* (Say)	crescent-shaped scar on husk or young nut	Lead arsenate	English (43)	69
YELLOW-POPLAR				
Tuliptree scale *Toumeyella liriodendri* (Gmel.)	scales on branches, twigs	Dormant spray	Craighead (34)	144

[1]The author is indebted to the Division of Forest Insects, Central States Forest Experiment Station, for material presented in this table.

[2]White grubs are injurious to nearly all tree species planted; for control measures see page 124.

[3]See Literature Cited, page 158.

Table 18.--Diseases of forest plantations[1]

Tree species and disease	Cause	Symptoms	Control
ASH, white and green Anthracnose	Marssonia fraxini	Large, irregular brown areas, numerous along leaf margin progressing inward to mid-veins.	No control practical in forest trees; on ornamentals use organic mercury (22)[2] or Bordeaux spray[3].
CATALPA Verticillium wilt	Verticillium albo-atrum	One to several branches wilt. Discolored streaks in sapwood of affected branches are first purple and later bluish brown.	Remove and burn infected trees (14).
COTTONWOOD Dothichiza canker	Dothichiza populea	Dark colored cankers on stems and branches which over a period of years enlarge and girdle the tree.	Plant disease-free stock avoid wounding (12) (114).
HACKBERRY Witches' broom	Gall mite--powdery mildew complex	Swelling, widening buds with enlarged, distorted bud scales; shoots are dwarfed and clustered, becoming broom-like in appearance.	No control (14) (22).

See footnotes at end of table.

Table 18.--Diseases of forest plantations (con.)

Tree species and disease	Cause	Symptoms	Control
LARCH, European Larch canker	Dasyscypha willkommii	Depressed branch and stem cankers with small white to orange, cup-like fruiting bodies around the edge.	This disease is believed to have been successfully eradicated from the U.S. Trees suspected of being infected with larch canker should be reported to the nearest State or Federal tree disease specialist (12) (14) (114).
LOCUST, black Verticillium wilt	Verticillium albo-atrum	Brownish streaks in wood, wilting branches.	No control (14) (22).
MAPLE, silver Nectria canker	Nectria cinnabarina	Target-shaped lesions with sloughing discolored, sunken bark which produce perennial cankers.	Tree removal, sanitation procedures; site improvement (14) (22).
Verticillium wilt	Verticillium albo-atrum	Greenish streaks in wood. Wilting branches generally followed by tree death.	No control (14) (22).
Tar spot	Rhytisma acerinum	Yellow-green spots which become shiny black, erupted and thickened.	No control (14) (22) (62).

Table 18.--Diseases of forest plantations (con.)

Tree species and disease	Cause	Symptoms	Control
OAKS			
Oak wilt	Ceratocystis fagacearum	Red oaks: leaves curl around midrib, bronze discoloration of leaves, severe defoliation, death of tree. White oak: similar to red oaks except that symptoms are often confined to one or several branches. White oaks may live for several years and some may recover.	Fell diseased trees and burn or spray top and stump with DDT, BHC, and 2,4,5-T (20) (57).
Twig blight	Sphaeropsis quercina	Dieback of twigs and branches accompanied by black streaking in the sapwood. Black fruiting bodies the size of a pin head in the dead bark. Infected trees are sometimes killed.	Prune out and burn all diseased wood (114).
Anthracnose	Gnomonia veneta	Brown, dead areas in the leaves, often triangular in shape, defoliation.	No control practical (12) (14) (114).
Leaf blister	Taphrina coerulescens	Circular, raised, wrinkled, yellowish areas on the leaves.	No control practical (14) (114).

Table 18.--Diseases of forest plantations (con.)

Tree species and diseases	Cause	Symptoms	Control
PINES			
Root rot	Fomes annosus	In plantations causes rapid decline and death of trees, usually in groups 3 or more years after first thinning; presence of thin white mycelial fans under bark of roots and root crown, with soft-stringy rot in wood; endemic in in natural stands, causing root and butt rot.	Careful planting to avoid root crowding and injury; increased spacing to defer need for thinning; treating stumps with creosote during thinning operations may help; avoid establishing new plantings in areas where root rot is prevalent; no practical control in natural stands (41) (53) (58) (94) (161).
Root and butt rot	Polyporus schweinitzii	Crowns become thin with short chlorotic needles, often clustered at ends of twigs; cones form prematurely; dark brown annual conks arise from roots or as brackets from trunk near base, and browning and death follow.	Avoid the establishment of pine plantations on sites with poor drainage or high pH (53) (180).

Table 18.--Diseases of forest plantations (con.)

Tree species and diseases	Cause	Symptoms	Control
PINES (con.)			
Shoestring root rot	Armillaria mellea	Decline in vigor of part or all of crown, followed by death, often involving groups of trees; may be sudden collapse in small trees; copius resin flow at base of trunk in pines; mycelial fans and rhizomorphs present under bark at base and roots; honey-colored mushrooms sometimes present.	Usually associated with weakened trees; no practical control (14) (29).
Dwarfmistletoe	Arceuthobium spp.	Witches' broom in the crown with fusiform swellings on infected branches; swollen trunk infections finally becoming cankerous, predisposing trees to windbreak; short fragile, yellow to green mistletoe shoots usually present in infected areas.	Remove infected trees in stand during logging operations; no infected trees should be left for seed source (14).
Needle cast	Spp. of Lophodermium, Hypoderma, Hypodermella, and Bifusella	Needles turn red or brown and are shed prematurely; tiny, black fruit bodies appear on infected needles, usually after they fall to the ground.	Control not practical in most cases; Lophodermium pinastri can be controlled with 8-8-100 Bordeaux spray[3] (14) (15).

Table 18.--Diseases of forest plantations (con.)

Tree species and diseases	Cause	Symptoms	Control
PINES (con.), 2-3 needled			
Gall and blister rusts	Cronartium spp.	Slightly spindle-shaped, fusiform, or globose swelling on twigs, branches, or stems, giving rise to white bladder-like fruit bodies which rupture in spring to expose orange-yellow spore masses; perennial cankers sometimes formed on trunk infections with certain Cronartium spp.	No control practical in forest stands; galls of Cronartium harknessii on ponderosa pine can be pruned off; certain silvicultural practices will reduce damage caused by Cronartium fusiforme in loblolly plantations (12) (14) (160).
Pine needle rusts	Coleosporium spp.	Small, white blister-like pustules on needles containing orange-yellow spore masses; repeated infection and defoliation on young trees cause reduction in growth; not serious on older trees.	No control usually warranted (14).
PINE, Austrian			
(See PINES and PINES, 2-3 Needled)			

Table 18.--Diseases of forest plantations (con.)

Tree species and diseases	Cause	Symptom	Control
PINE, Jack Needle blight	Elytroderma deformans	Red discoloration of foliage followed by browning and death; causes conspicuous witches' brooms on twigs of Ponderosa pine, but not on jack pine; browned needles have small, narrow, dull-black fruit bodies scattered over surface; young stands are severely damaged.	No control practical except for salvage cuttings in severely damaged stands (28).
PINE, loblolly Littleleaf disease	Phytophthora cinnamoni in conjunction with adverse soil conditions, including poor aeration, low fertility, and moisture stress.	Early stages resemble symptoms of nitrogen deficiency; in advanced stages the crown is sparse and foliage appears in tufts at twig tips; needles are markedly shortened and yellow to yellow-green in color; sprouts develop on lower trunk, and trees produce large crops of small cones; disease rare on trees under 20 years.	Losses in forest stands can be reduced by following certain cutting practices designed to eliminate diseased trees; on park trees applications of commercial fertilizer prevent symptom development and improve conditions of trees in early stages of littleleaf (182).
Fusiform rust (See PINES, 2-3 Needled)			
PINE, Ponderosa Needle blight (See PINE, jack)			

Table 18.--Diseases of forest plantations (con.)

Tree species and diseases	Cause	Symptoms	Control
PINE, (con.) red			
Tympanis canker	Tympanis spp.	Produces annual sunken cankers on main stems at branch whorls; cankers inconspicuous until dead bark sloughs off; attacks red pine in plantings out of optimum range for species.	Avoid establishment of red pine plantations south of optimum range for species; damage on white pine is inconsequential, and no control necessary. (12) (14)
Resinosis	Incompletely understood, usually associated with tight, poorly drained or alkaline soils and fungus infections, especially Polyporus schweinitzii	Progressive dying from the top downward, accompanied by resin flow at the butt and a white mottling of inner bark.	Avoid plantings on tight, poorly drained soil (60) (180).
PINE, Scotch			
(See PINES and PINES, 2-3 Needled)			
PINE, Shortleaf			
Littleleaf disease			
(See PINE, loblolly)			
Pitch canker	Fusarium lateritium f. pini	Copious pitch flow from cankers on stems and branches; underlying wood is characteristically pitch-soaked; white mycelial growth sometimes evident in cankers under bark.	Remove infected trees in thinning operations or other improvement cuttings (13).
PINE, Virginia			
Pitch canker			
(See PINE, shortleaf)			

Tree species and diseases	Cause	Symptoms	Control
PINE, (con.) white			
White pine blister rust	Cronartium ribicola	The most conspicuous symptoms are the spindle-shaped swellings on branches and stems bearing numerous white blisters filled with orange powdery spore masses. The swellings enlarge annually, become cankerous and produce successive crops of spores which infect ribes bushes, the alternate host; cankers eventually girdle and kill infected stems.	Destroy ribes bushes in white pine stands and in a protective zone of 500 to 1000 feet around the stands. Width of protective zone varies with climate, elevation, latitude, and species of pine and ribes hosts (93).
Resinosis (See PINE, red)			
Chlorotic dwarf	Unknown	Progressive shortening of needles and internodes, resulting in dwarfed trees which eventually die; in advanced stages only the current year's needles are present which become chlorotic and occasionally exhibit tip burn; disease is commonly found in plantations up to 15 years old.	No control known (143).
Eastern white pine blight needle blight	A disease complex, apparently of physiogenic origin which may prove to be several distinct entities. In some cases associated with water deficiencies and nutritional imbalance.	Browning and death of the outer portions of the current year's needles. May cause reduced increment; needles sometimes shortened and drop prematurely; repeated attacks may cause death; occurs both in natural stands and in plantations.	No control generally applicable. Fertilization and other soil improvement measures have shown promise and are practical only where small numbers of trees are involved (37) (144).

Table 18.--Diseases of forest plantations (con.)

Tree species and diseases	Cause	Symptoms	Control
REDCEDAR, Eastern			
Cedar-apple rust	Gymnosporangium juniperi-virginianae	Globose, pitted swellings or galls on twigs and foliage producing conspicuous orange telial horns during rainy periods.	Avoid planting within 1 mile of apple, pear, hawthorn, or mountain ash trees (12) (14) (114).
Cedar blight	Phomopsis junipovora	Twig dieback accompanied by small brown cankers or lesions on the smaller branches.	Remove and burn all dead branch tips (12) (14) (114).
Fomes root rot (See PINES)			
SPRUCE, Norway			
Cytospora canker	Cytospora kunzei	Browning of needles, dying lower branches, resin flow.	Prune out and destroy all diseased material, plant on suitable sites, maintain vigor (12) (14) (114).
Fomes root rot (See PINES)			
Sphaeropsis tip blight	Sphaeropsis ellisii	Brown needles and twig dieback at the ends of branches. Minute black fruiting bodies at base of affected needles and in dead bark.	Cut and burn diseased portions of tree; spraying with organic mercury or Bordeaux may be justified in Christmas tree plantations[3] (12) (22).
SWEETGUM			
Sweetgum blight	Incompletely understood, but probably caused primarily by moisture shortages influenced by low rainfall, tight soils, or lowering of water table	General decline of tree resulting in stag heading and in some cases death.	No control known (145).

Table 18.--Diseases of forest plantations (con.)

Tree species and diseases	Cause	Symptoms	Control
SYCAMORE			
Anthracnose	Gnomonia veneta	Leaves and twig tips brown and die upon emergence from buds (resembles frost injury); later symptoms show brown spots along main veins that coalesce to kill leaves; twigs killed by small cankers.	No control; on ornamentals use Bordeaux or organic mercury sprays[3]. (14) (22)
WALNUT, Black			
Anthracnose	Gnomonia leptostyla	Irregular dark brown or blackish spots on leaflets, branch tips are killed; plant defoliates.	No control; on ornamentals use Bordeaux sprays[3] (114) (167).
Walnut blight	Xanthomonas juglandis	Black, necrotic spots occur on nuts, leaves, and spring shoots.	No control; on ornamentals use Bordeaux sprays[3] (114) (167).
YELLOW-POPLAR			
Nectria canker	Nectria magnoliae	Elliptical cankers beneath cracking bark.	No control (14).

[1]The author is indebted to the Division of Forest Diseases, Central States Forest Experiment Station, for material presented in this table.

[2]Numerals in parentheses denote references (see page 158) that contain more information on the disease.

[3]Bordeaux mixture is used at the rate of 8-8-100, two or three applications, applied every 14 to 21 days, starting when the leaves emerge in the spring. Bordeaux mixture is prepared by dissolving 8 pounds of copper sulfate in 100 gallons of water. Eight pounds of hydrated lime are mixed with a small amount of water and the suspension added to the copper sulfate solution in the spray tank and agitated.

Organic mercury recommended is 10 percent phenylmercury-acetate or 7.5 percent phenylmercury-triethanolammonium-lactate, used at the rate of 1 pint per 100 gallons of water, applied three to five times at seven-to-ten-day intervals, starting when the leaves emerge in the spring.

Common and Scientific Names of Trees Mentioned

Alder, European	*Alnus glutinosa* (L.) Gaertn.
Alder, speckled (European)	*A. incana* (L.) Moench
Ash, green	*Fraxinus pennsylvanica* Marsh.
Ash, white	*F. americana* L.
Baldcypress	*Taxodium distichum* (L.) Rich.
Boxelder	*Acer negundo* L.
Crab apple	*Malus* Mill. spp.
Catalpa, northern	*Catalpa speciosa* Warder
Cottonwood	*Populus deltoides* Bartr.
Elm, red (slippery elm)	*Ulmus rubra* Muhl.
Hackberry	*Celtis occidentalis* L.
Juniper, Rocky Mountain	*Juniperus scopulorum* Sarg.
Larch, European	*Larix decidua* Mill.
Laurel (mountain laurel)	*Kalmia latifolia* L.
Locust, black	*Robinia pseudoacacia* L.
Maple, red	*Acer rubrum* L.
Maple, silver (soft maple)	*A. saccharinum* L.
Oak, black	*Quercus velutina* Lam.
Oak, bur	*Q. macrocarpa* Michx.
Oak, chestnut	*Q. prinus* L.
Oak, northern red	*Q. rubra* L.
Oak, pin	*Q. palustris* Muenchh.
Oak, white	*Q. alba* L.
Osage-orange	*Maclura pomifera* (Raf.) Schneid.
Persimmon, common	*Diospyros virginiana* L.
Pine, Austrian	*Pinus nigra* Arnold.
Pine, jack	*P. banksiana* Lamb.
Pine, loblolly	*P. taeda* L.
Pine, longleaf	*P. palustris* Mill.
Pine, pitch	*P. rigida* Mill.
Pine, ponderosa	*P. ponderosa* Laws.
Pine, red	*P. resinosa* Ait.
Pine, Scotch	*P. sylvestris* L.
Pine, shortleaf	*P. echinata* Mill.
Pine, Virginia	*P. virginiana* Mill.
Pine, white (eastern white)	*P. strobus* L.
Redcedar, eastern	*Juniperus virginiana* L.
Rhododendron	*Rhododendron* L. spp.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Sourwood	*Oxydendrum arboreum* (L.) DC.
Spruce, Norway	*Picea excelsa* Link
Spruce, white	*P. glauca* (Moench) Voss
Sweetgum	*Liquidambar styraciflua* L.
Sycamore, American	*Platanus occidentalis* L.
Walnut, black	*Juglans nigra* L.
Willow	*Salix* L. spp.
Yellow-poplar (tulip tree)	*Liriodendron tulipifera* L.